Manufacturing Technologies

Instructor Guide

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Advanced Technological Education

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Learning Unit Overview

Learning Unit Purpose

As our nation's economy, society at large, and environment are increasingly influenced by technological innovations it is imperative that our educational system is able to keep pace and is able to prepare students for highly technical careers. This Project ProBase Learning Unit, titled *Manufacturing Technologies,* is designed to help prepare high school students who plan to go on to community college technical education or university-level engineering programs.

This unit is one of eight Learning Units developed by Project ProBase to address the critical need for upper high school technology education curriculum. The Project ProBase Learning Units utilize hands-on, problem-based activities to introduce fundamental technology concepts related to each context area standard identified in *Standards for Technological Literacy: Content for the Study of Technology* published by the International Technology Education Association.

You may be interested in the other Learning Units developed by Project ProBase:	
• *Agriculture and Related Biotechnologies*	• *Construction Technologies*
• *Entertainment and Recreation Technologies*	• *Energy and Power Technologies*
• *Information and Communication Technologies*	• *Manufacturing Technologies*
• *Medical Technologies*	• *Transportation Technologies*

Constructivist-based Teaching and Learning

Each Learning Unit is driven by authentic open-ended problems offering multiple opportunities for students to construct knowledge about the world around them. Constructivism is a learning theory based on the belief that humans learn best when they construct their own knowledge based on their experiences.

One goal of the ProBase Learning Units is to provide a variety of authentic, contextually-based experiences that students can use to construct accurate knowledge and develop appropriate skills across the contexts of technology. Constructivist learning is accomplished by providing experiences and opportunities that encourage students to construct accurate knowledge. Each Learning Unit considers the student as a creator of knowledge and assumes that the teacher will facilitate this acquisition of knowledge. This is contrary to the notion that teachers are "dispensers" of knowledge and requires a paradigm shift for some.

As facilitators of learning, ProBase instructors will need to prepare for class in a slightly different way. Students will still need materials and equipment as they engage in activities.

Instructors should review all of the learning cycles in advance so that they know what materials and equipment to gather as well as what types of demonstrations must be provided. Another important reason for reviewing the learning cycles is to begin thinking about appropriate questions to ask the students. Sample questions are provided in the *Reflection* phase of each learning cycle. However, the instructor may want to go beyond these questions to probe student thinking to find out the technological perspective students bring to the class. The instructor should ask questions that challenge student thinking and present new ideas that help students create conceptual change.

Connecting Standards for Technological Literacy: Content for the Study of Technology

Enduring Understandings

Each Learning Unit developed by Project ProBase was developed to address three to four enduring understandings derived from *Standards for Technological Literacy: Content for the Study of Technology* (STL) published by the International Technology Education Association (2000/2002). According to Wiggins and McTighe in *Understanding by Design* (1998, p. 10), an enduring understanding "refers to the big ideas, the important understandings, that we want students to 'get inside of' and retain after they've forgotten many of the details."

In an effort to distill the enduring understandings from *STL*, each standard was filtered through the following questions:

- Does the standard represent a big idea having enduring value beyond the classroom?
- Does the standard reside at the heart of the discipline?
- Does the standard require uncoverage of abstract and often misunderstood ideas?
- Does the standard offer potential for engaging students?

This process yielded nine enduring understandings. For a complete list of enduring understandings along with corresponding essential questions, see appendix page AA.

Students will understand:

1. That technological progression is driven by a number of factors, including individual creativity, product and systems innovations, and human wants and needs.

2. That technological development for the solution of a problem in one context can spinoff for use in a variety of often unrelated applications.

3. That technological change can be positive and/or negative and can have intended and/or unforeseen social, cultural, and environmental consequences.

4. How technological systems work, the components of those systems, and how they fit into the larger technological, economic, and social systems.

5. The compelling and controversial issues associated with the acquisition, development, use, and disposal of resources.

6. That the complexities of technological design involve trade-offs among competing constraints and requirements, including engineering, economic, political, social, and environmental considerations.

7. That technological design is a systematic process used to initiate and refine ideas, solve problems, and maintain products and systems.

8. How technological assessment is used to determine the benefits, limitations, and risks associated with existing and proposed technologies.

9. How to utilize a variety of simple and complex technologies.

Essential Questions

Each enduring understanding must be "unpacked" to be meaningful for learning and instruction. Therefore, each enduring understanding has several essential questions associated with it. The essential questions are addressed through the learning cycles.

Bridge Competencies

In addition to focusing on the enduring understandings derived from *STL*, each Learning Unit helps to address a set of Bridge Competencies developed in conjunction with a consortium of central Illinois community college partners. Representatives from this consortium reviewed each Learning Unit to identify where the Bridge Competencies were being addressed. Each Learning Unit contains a matrix that reflects which Bridge Competencies are addressed in that specific Learning Unit.

Learning Unit Framework

Each Learning Unit developed by Project ProBase follows a similar format in an effort to be consistent and true to a constructivist-based curriculum.

Preliminary Challenge

Students will be introduced to the Learning Unit through a hands-on activity designed to pique their interest and begin to establish a focus for the Learning Unit.

Primary Challenge

Next the students are introduced to a robust *Primary Challenge,* far too complex to be solved at this point in the unit. Students will be asked to reflect on the knowledge and skills needed to reach a plausible solution to this challenge. This instructor-led discussion happens just before the students are led through a series of four-phase learning cycles designed to develop the knowledge and skills necessary to successfully complete the *Primary Challenge*. Time is provided throughout the nine-week Learning Unit to actually work on a solution to the *Primary Challenge*.

Four-phase Learning Cycles

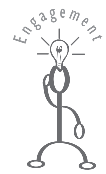
In order to develop plausible solutions for the *Primary Challenge*, students must gain accurate knowledge and appropriate skills throughout each Learning Unit. The learning experiences found in the Project ProBase curriculum are developed using a four-phase learning cycle.

Phase one: Exploration

During this phase of each learning cycle, students will be exploring selected concepts while engaged in hands-on activities. The explorations are done individually as well as in teams. The goal of the *Exploration* phase is to have students construct accurate knowledge about each concept under investigation.

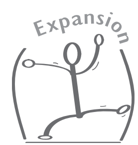
Phase two: Reflection

The *Reflection* phase of the learning cycle offers an opportunity for students to think about what they know about the concepts under investigation. Their reflections are recorded in an Inventor's Logbook that can be used to check their understanding. This phase of the learning cycle also provides an opportunity for the instructor to clear up lingering misconceptions and to be sure that all students are ready to move on.



Phase three: Engagement

The *Engagement* phase of the learning cycle allows the students to apply the knowledge and skills that they are constructing. This phase reinforces their understanding of the important concepts. The activities that students are engaged in are as authentic as possible and are often team activities.



Phase four: Expansion

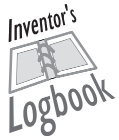
This phase of the learning cycle is where students can extend their new understandings to new situations. Students should select one of the activities from the several that are suggested. Some of the *Expansion* activities are designed to be done as individuals as homework and some are team activities.

Student and Instructor Roles During Each Phase of the Learning Cycle

Learning Cycle Phase	Student's Role	Instructor's Role
Exploration	• Interacts with materials and equipment • Collects, records, and analyzes data • Designs solutions • Investigates concepts	• Asks questions • Gathers materials • Oversees safety and skills instruction • Encourages Inventor's Logbook entries
Reflection	• Answers questions in Inventor's Logbook • Forms generalizations • Compares team data • Participates in discussions	• Questions students • Leads class discussions • Corrects misconceptions • Facilitates class data sets
Engagement	• Applies concepts, principles, theories • Designs and builds solutions • Solves problems	• Supplies materials • Keeps students on task • Corrects lingering misconceptions • Assures safe practice
Expansion	• Extends concepts to different contexts • Researches • Journals in Inventor's Logbook	• Provides appropriate resources • Questions students to ensure connections are made to broader context

Preparing for the Challenge

A goal of the Project ProBase curriculum is to have students work toward the *Primary Challenge* throughout each Learning Unit. Therefore, at the end of each learning cycle students are asked to reflect on the *Primary Challenge*. In many cases the student is provided time to work on the solution to the *Primary Challenge* for a day or two between learning cycles.



Inventor's Logbook

Each Learning Unit developed by Project ProBase makes use of an Inventor's Logbook. An icon like the one above is placed throughout the Learning Unit whenever students are expected to answer specific questions, record data, or write down their observations. The specific requirements for this logbook are left for you to determine.

The Inventor's Logbook entries will also be used to check and assess student progress toward the concepts that each learning cycle is focused on. The rubrics provided at the end of each learning cycle contain an Inventor's Logbook element where the specific concepts are identified. This will encourage your students to make regular entries in their student text and provide dynamic documentation of their progress.

Student Assessment

Student assessment is an important component in the ProBase curriculum. The Instructor's Guide provides several optional rubrics to use for formative and summative student evaluation. The Inventor's Logbook is designed to be a formative assessment of student progress. The Instructor's Guide contains a rubric for assessing each student's Inventor's Logbook. In addition, each *Primary Challenge* has a rubric for summative evaluation.

The *Engagement* phase of each learning cycle affords a unique opportunity to assess student progress. Therefore, a rubric unique to the *Engagement* phase is provided as often as possible.

Rubrics have been inserted in the Instructor's Guide and Student's Guide for assessing a student's contribution to teamwork and daily engagement/preparation.

Materials and Equipment

The Project ProBase curriculum is designed to be taught in a general technology laboratory facility. Each learning cycle details the equipment and materials needed for that specific activity. Each Learning Unit also includes a compiled list of all the equipment and materials needed for the unit in the front of the Instructor's Guide. By design and as much as possible, the equipment and materials used for the activities are easy to find, over-the-counter materials. Where appropriate and necessary, specific vendors have been identified and their contact information has been provided.

Learning Cycle One:
2a. *How do technologies migrate from one context (or location) to another and what are the implications?*

Learning Cycles Five and Six:
4b. *What are the key elements of the various technological systems and what are the relationships between these systems?*

Learning Cycle One:
6b. *What are the key factors that cause designers to make decisions about trade-offs, limitations, and constraints when designing new products and systems? (Micro Factors)*

Learning Cycle Three:
7b. *To what extent can design problems be approached through a series of generic procedures (the design loop)?*
Learning Cycles One, Two & Three:
7c. *What design criteria is typically considered when developing new technologies (i.e., marketability, safety, useability, reliability, cost, materials, etc.) and how do these influence the final product/system design?*
Learning Cycle Two:
7e. *How can the attributes of design and the principles of design aid in the development of quality solutions?*

Learning Cycles Four and Six:
9a. *How are technologies used to control devices and systems?*
Learning Cycle Four:
9b. *How do technologies communicate with one another and provide information to humans?*
Learning Cycle Five:
9d. *How is technological instrumentation used to measure, calculate, manipulate, and predict the actions of technological devices and systems?*

Manufacturing Technologies Overview

Up to this point, we have been discussing the Project ProBase Learning Units in general terms. The following points will be specific to *Manufacturing Technologies.*

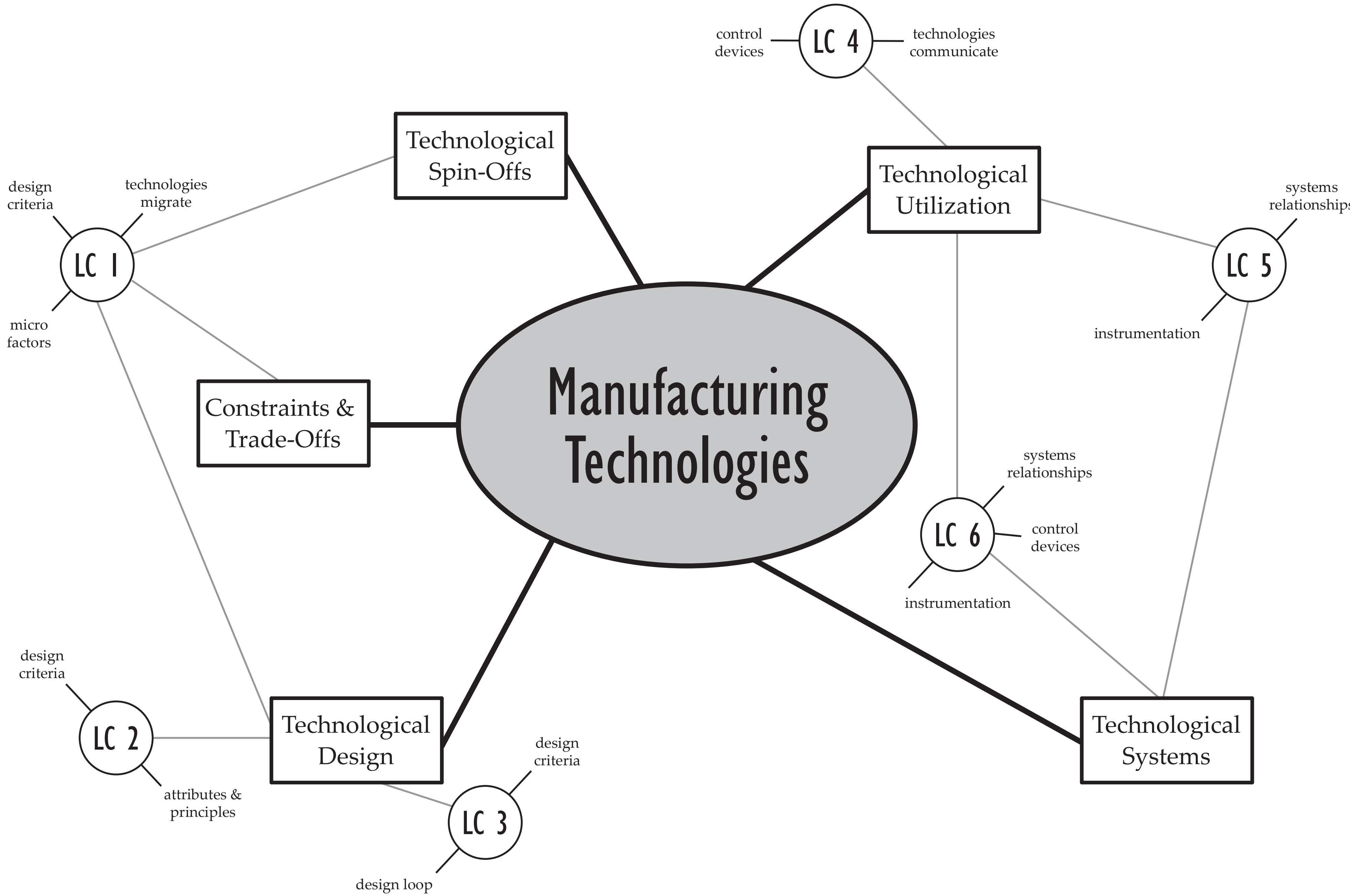
Enduring Understandings and Essential Questions

The *Manufacturing Technologies* Learning Unit focuses on three of the nine enduring understandings. As they complete *Manufacturing Technologies* students will understand:

2. that technological development for the solution of a problem in one context can spinoff for use in a variety of often unrelated applications.
4. how technological **systems** work, the components of those systems, and how they fit into the larger technological, economic, and social systems.
6. that the complexities of technological design involve trade-offs among competing constraints and requirements, including engineering, economic, political, social, and environmental considerations.
7. that technological design is a systematic process used to initiate and refine ideas, solve problems, and maintain products and systems.
9. how to utilize a variety of simple and complex technologies.

The essential questions addressed in each learning cycle are correlated to the learning cycle objectives.

Manufacturing Technologies Learning Unit Concept Map



Manufacturing Technologies Learning Unit Materials List

Learning Unit Consumables (based on a class size of 28 students)

Qty.	Item	Learning Cycle	Notes and Recommended Options
1 gallon	Liquid hand soap	Primary	www.chemistrystore.com
3	Different soap colors	Primary	www.chemistrystore.com
3	Different soap scents	Primary	www.chemistrystore.com
12	Film canisters	Primary	Could use other containers suitable for liquid soap
	Rubber/plastic tubing	Primary	
	Wood	Primary	Various lengths, miscellaneous
	Nails	Primary	
7	Oscar Mayer Lunchables® brand containers	1	Or another brand
9 to 12	Bars of soap	1	Three distinctly different types and national brands
7	Flip Charts of Paper	1	
	Markers	1	
1 bag	Paper Clips	2	
	Aluminum Foil	2	
	Soap	2	

28 pairs	Disposable plastic gloves	2	

Learning Unit Consumables cont'd

Qty.	Item	Learning Cycle	Notes and Recommended Options
7 bags	Raisins (1 bag per group)	2	
7 bags	Peanuts (1 bag per group)	2	
7 bags	M & M's (1 bag per group)	2	
7 bags	Sunflower Seeds (1 bag per group)	2	
7 bags	Marshmallow (optional instead of peanuts)	2	
4 boxes	Ziploc bags	2	
1 box	Paper Bowls	2	
15-20	Flashlights	3	Inexpensive; can be disassembled
7	9-volt Batteries	4	
7	Rods	4	Wood, metal, or other material
7	Short lengths of wood	4	
	Small tension or machine screws	**4**	
21	AA Batteries	4, 5	

Learning Unit Equipment

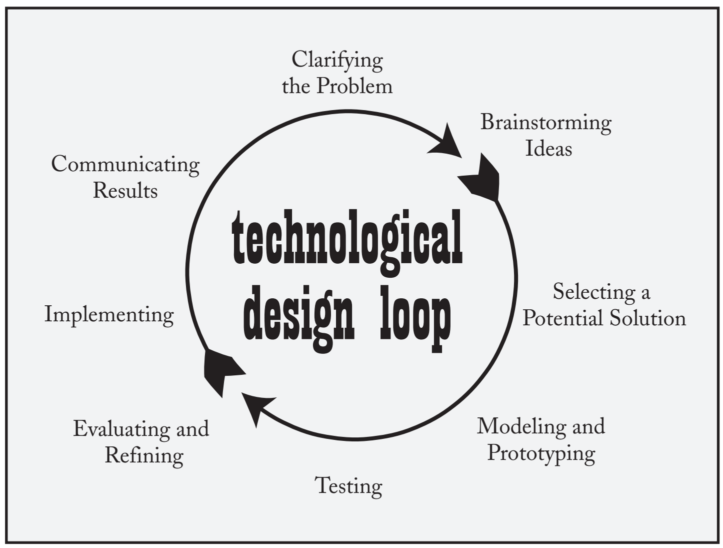
Qty.	Item	Learning Cycle	Notes and Recommended Options
7	Fabricated products can be disassembled	Prelim.	Toaster, mixer, blender, electric drill, power saw
7	Hand or power tools	Prelim.	Screwdriver, pliers, etc.
7	BASIC Stamp HomeWork Board	Primary, 4, 5, 6	www.parallax.com, part #28158
7 packages	Electronic Components for HomeWork Boards	Primary, 4, 5, 6	resistors, capacitors, LEDS, jumper wires, etc.
7	BASIC Stamp serial programming cables	Primary, 4, 5, 6	www.parallax.com, part #800-00003
1	BASIC Stamp Editor version 2.1 software	Primary, 4, 5, 6	www.parallax.com
7	Standard servos	Primary, 4, 6	www.parallax.com, part #900-00005
1	Inductive proximity sensor	Primary, 5	
1	Float switch	Primary, 5	
1	Contact sensor	Primary, 5	
1	Foot switch	Primary, 5	
7	Relays	Primary, 6	
	Nails	Primary, 6	
	Screws	Primary, 6	
7	Products	1	Various household products
7	Timers (1 per group)	2	
7	Gram scales	2	

Learning Unit Equipment cont'd

Qty.	Item	Learning Cycle	Notes and Recommended Options
	Measuring cup set	2	1 C, 1/2 C, 1/4C
5 to 10	Plastic bowls	2	Large size
5	Flashlights	3	All different, from very simple to very complex
	Ring stands and clamps	4	From the Chemistry department
7	T-connectors	4	Kelvin
14	Containers	4	
7	2-AA Battery Packs	4, 5	
4	Alligator clips and wire	5	
	Sheet metal	6	
7	Ink pen springs	6	
7	1-AA battery holder	6	
	Electrical wire	6	
7	Solenoids (possibly have double on hand)	6	
7	Dip Relays	6	

the Technological Design Loop

As a constructivist, problem-based curriculum, the ProBase Learning Units offer a variety of opportunities for students to engage in design activities. The ProBase Learning Units have been developed for upper high school technology education students. It is assumed that students engaging in the ProBase curriculum possess some prerequisite knowledge and skills regarding engineering design. If students do not have previous experience in this area, it may be necessary to provide a brief introduction to design-based problem solving. It is suggested that you use the following design model adapted for the ProBase curriculum from *Standards for Technological Literacy* (International Technology Education Association, 2000/2002).



If you see a need to introduce the design-based problem solving process, it is suggested that you do so in a constructivist manner using a simple design problem. For example, you might have your students use the model presented above as they design a cover for a book or CD. You should attempt to use media beyond paper and pencil such as modeling clay, Styrofoam™, Balsa wood, or cardboard. Other simple design ideas include designing paper airplanes, a package for their favorite snack, a marketing flyer for a new product, an ergonomic handle for a shaving razor, or prototype cardboard seat or a model of other furniture pieces.

Manufacturing Technologies Unit Calendar

Week	Day 1	Day 2	Day 3	Day 4	Day 5
1	Course Introduction; Preliminary Challenge	Preliminary Challenge	Preliminary Challenge	Preliminary Challenge	Intro to Primary Challenge; Enduring Understandings
2	Learning Cycle 1 - *Exploration*	Learning Cycle 1 - *Exploration, Reflection*	Learning Cycle 1 - *Engagement*	Learning Cycle 1 - *Engagement*	Preparing for the Primary Challenge
3	Learning Cycle 2 - *Exploration*	Learning Cycle 2 - *Exploration*	Learning Cycle 2 - *Reflection*	Learning Cycle 2 - *Engagement*	Learning Cycle 2 - *Engagement* Preparing for the Challenge
4	Learning Cycle 3 - *Exploration*	Learning Cycle 3 - *Reflection, Engagement*	Learning Cycle 3 - *Engagement*	Learning Cycle 3 - *Engagement* Preparing for the Challenge	Learning Cycle 4 - *Exploration, Reflection*
5	Learning Cycle 4 - *Engagement*	Learning Cycle 4 - *Engagement*	Learning Cycle 4 - *Engagement* Preparing for the Challenge	Learning Cycle 5 - *Exploration I* *Reflection I*	Learning Cycle 5 - *Exploration II* *Reflection II*
6	Learning Cycle 5 - *Engagement*	Learning Cycle 5 - *Engagement* Preparing for the Challenge	Learning Cycle 6 - *Exploration*	Learning Cycle 6 - *Exploration*	Learning Cycle 6 - *Reflection, Engagement*
7	Learning Cycle 6 - *Engagement*	Learning Cycle 6 - *Engagement* Preparing for the Challenge	Preparing for the Primary Challenge	Preparing for the Primary Challenge	Preparing for the Primary Challenge
8	Preparing for the Primary Challenge	Preparing for the Primary Challenge	Preparing for the Primary Challenge	Primary Challenge	Primary Challenge
9	Primary Challenge	Primary Challenge	Primary Challenge	Presentations of the Primary Challenge	Presentations of the Primary Challenge

*For block scheduling, adjust the Unit Calendar appropriately

Manufacturing Technologies

Table of Contents

Preliminary

Preliminary and Primary Challenges

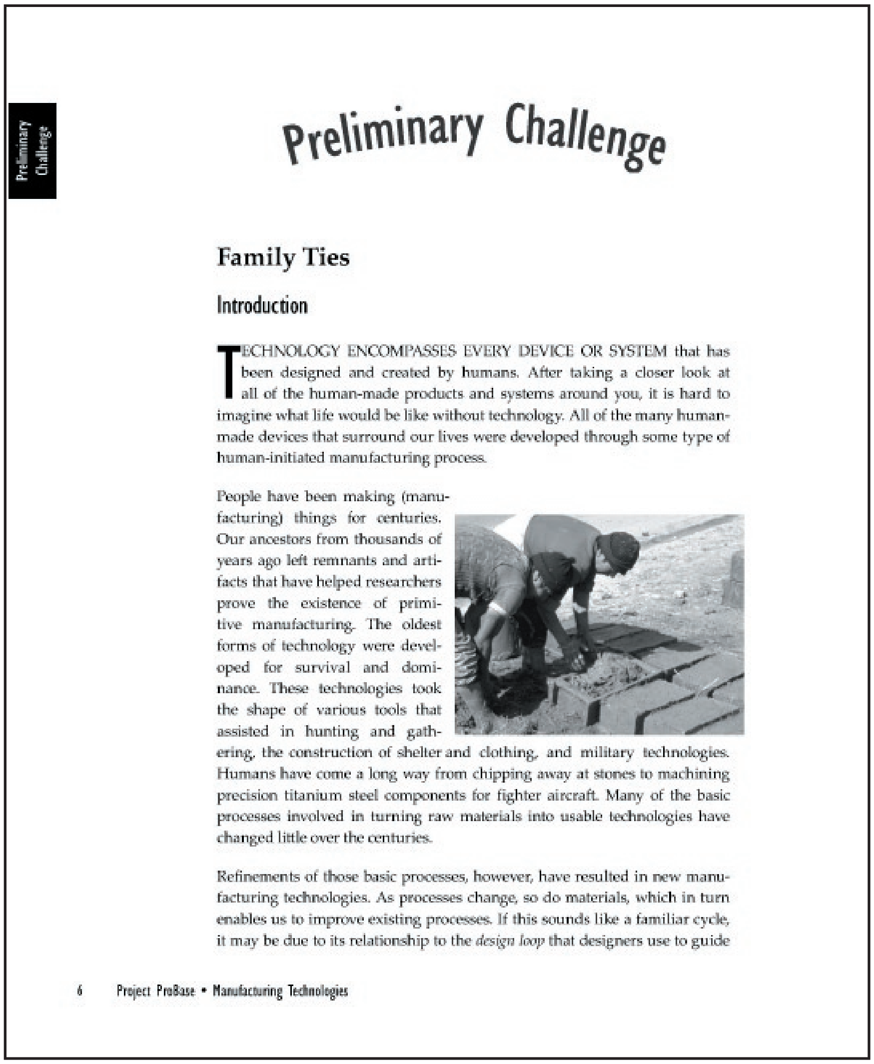
Primary

Family Ties

Introduction

The purpose of this *Preliminary Challenge* is to introduce students to the Learning Unit through a hands-on, minds-on activity. Students should begin to see that technological artifacts are manufactured through the utilization of basic materials and processes.

Students will be exploring fabricated products comprised of multiple components and materials. As they disassemble their products, they will be trying to identify the materials and processes that were originally used in the manufacture of these products.


Preliminary Challenge

Preliminary Challenge

Family Ties

Introduction

TECHNOLOGY ENCOMPASSES EVERY DEVICE OR SYSTEM that has been designed and created by humans. After taking a closer look at all of the human-made products and systems around you, it is hard to imagine what life would be like without technology. All of the many human-made devices that surround our lives were developed through some type of human-initiated manufacturing process.

People have been making (manufacturing) things for centuries. Our ancestors from thousands of years ago left remnants and artifacts that have helped researchers prove the existence of primitive manufacturing. The oldest forms of technology were developed for survival and dominance. These technologies took the shape of various tools that assisted in hunting and gathering, the construction of shelter and clothing, and military technologies. Humans have come a long way from chipping away at stones to machining precision titanium steel components for fighter aircraft. Many of the basic processes involved in turning raw materials into usable technologies have changed little over the centuries.

Refinements of those basic processes, however, have resulted in new manufacturing technologies. As processes change, so do materials, which in turn enables us to improve existing processes. If this sounds like a familiar cycle, it may be due to its relationship to the *design loop* that designers use to guide

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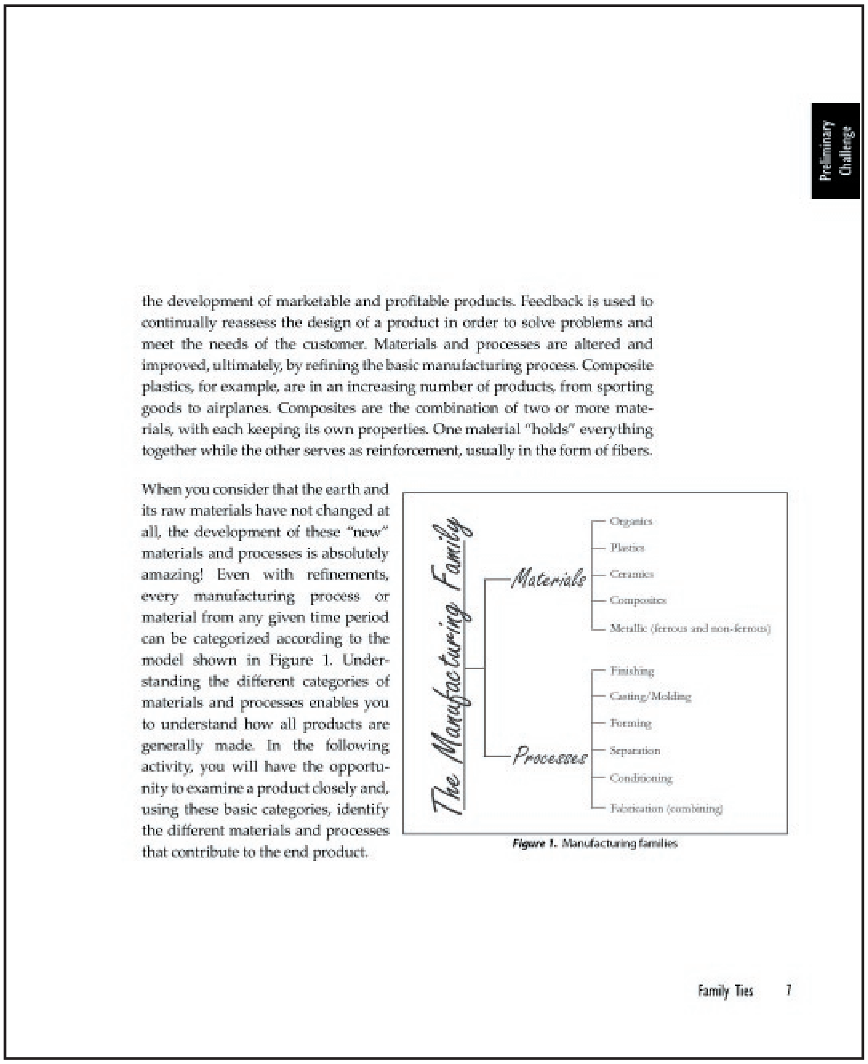
Key Concepts

Each Learning Unit is designed to facilitate several enduring understandings. The key concepts have been synthesized from the enduring understandings and essential questions and will focus the learning cycles in this Learning Unit. Each learning cycle is keyed to one or more of the following enduring understandings:

Students will understand:

2. that **technological** development for the solution of a problem in one context can **spinoff** for use in a variety of often unrelated applications.
6. that the complexities of technological **design** involve trade-offs among competing **constraints** and requirements, including engineering, economic, political, social, and environmental considerations.
7. that **technological design** is a systematic process used to initiate and refine ideas, solve problems, and maintain products and systems.
9. how to **utilize** a variety of simple and complex technologies.



Preliminary Challenge

the development of marketable and profitable products. Feedback is used to continually reassess the design of a product in order to solve problems and meet the needs of the customer. Materials and processes are altered and improved, ultimately, by refining the basic manufacturing process. Composite plastics, for example, are in an increasing number of products, from sporting goods to airplanes. Composites are the combination of two or more materials, with each keeping its own properties. One material "holds" everything together while the other serves as reinforcement, usually in the form of fibers.

When you consider that the earth and its raw materials have not changed at all, the development of these "new" materials and processes is absolutely amazing! Even with refinements, every manufacturing process or material from any given time period can be categorized according to the model shown in Figure 1. Understanding the different categories of materials and processes enables you to understand how all products are generally made. In the following activity, you will have the opportunity to examine a product closely and, using these basic categories, identify the different materials and processes that contribute to the end product.

The Manufacturing Family
Materials
Organics
Plastics
Ceramics
Composites
Metallic (ferrous and non-ferrous)
Processes
Finishing
Casting/Molding
Forming
Separation
Conditioning
Fabrication (combining)

Figure 1. Manufacturing families

Family Ties 7

Facility Requirements

This activity can be conducted in any environment as long as students can gather throughout the room in small teams.

Equipment and Materials

Based on a class of 28 students:

Each team of students will need a fabricated product that has multiple components and materials. Suggested products include kitchen appliances such as a toaster, mixer, or blender or power tools such as an electric drill, a power saw, etc. You will also need the "Materials and Processes Evaluation Form" sheet, found in each Student Guide.

Preliminary Challenge

Learning Unit Goal

The Learning Unit goal provides a target for the Manufacturing Learning Unit. As students complete this unit, they will be able to:

Utilize appropriate design principles while developing an automated manufacturing machine.

Suggested Daily Outline

Day One	Day Two
Introduction, *Disassemble products*	*Disassemble products*
Day Three	**Day Four**
Reflection, Begin "Materials and Processes Evaluation Form"	Complete "Materials and Processes Evaluation Form," and reassemble product
Day Five	
Introduction to *Primary Challenge,* Enduring Understandings activity	

Estimated Number of 50-minute class periods: **5**

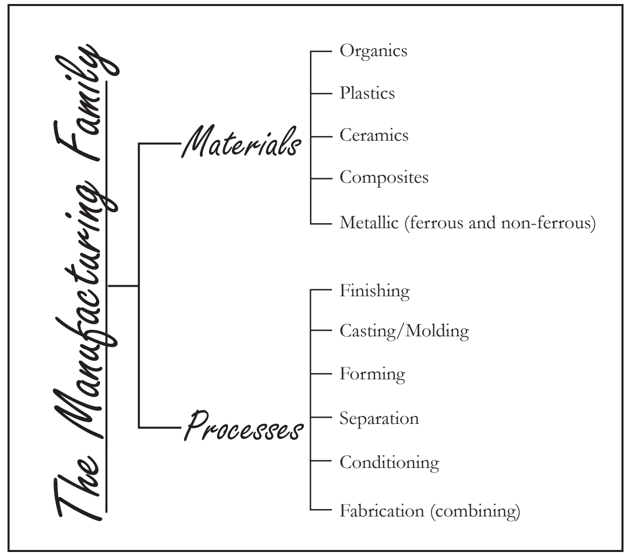
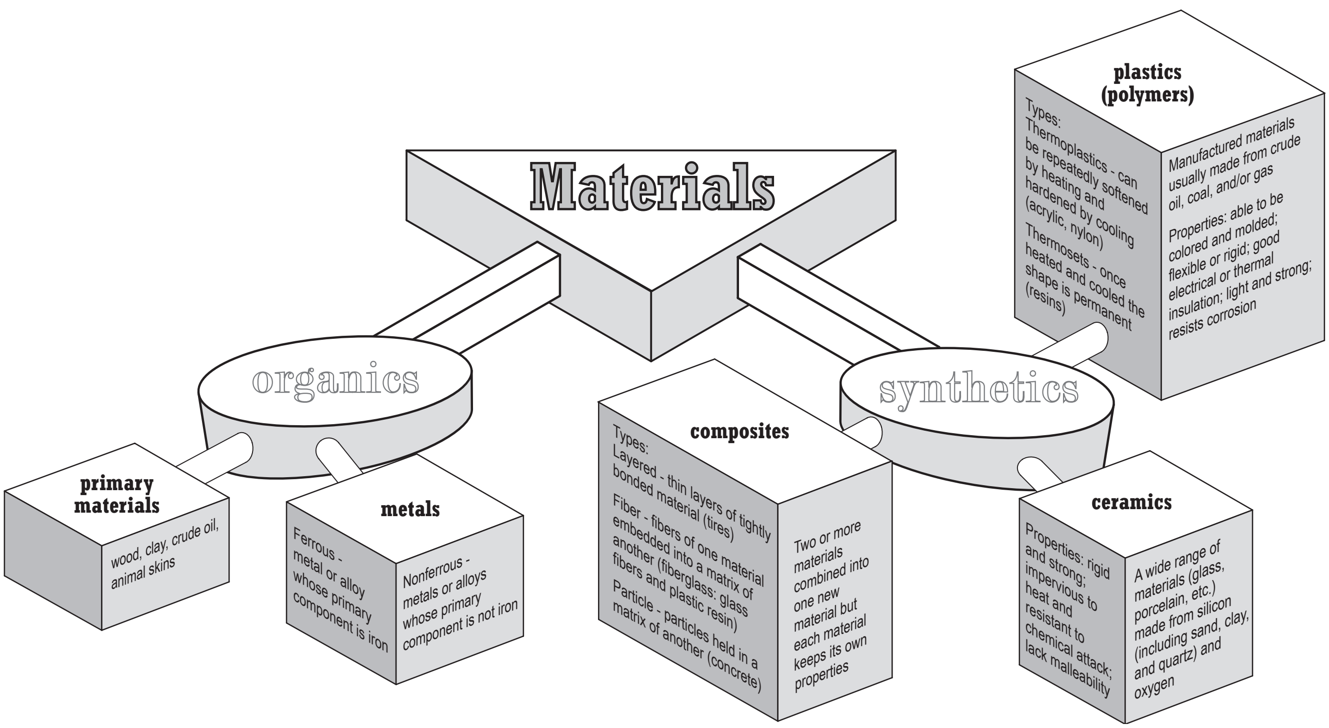
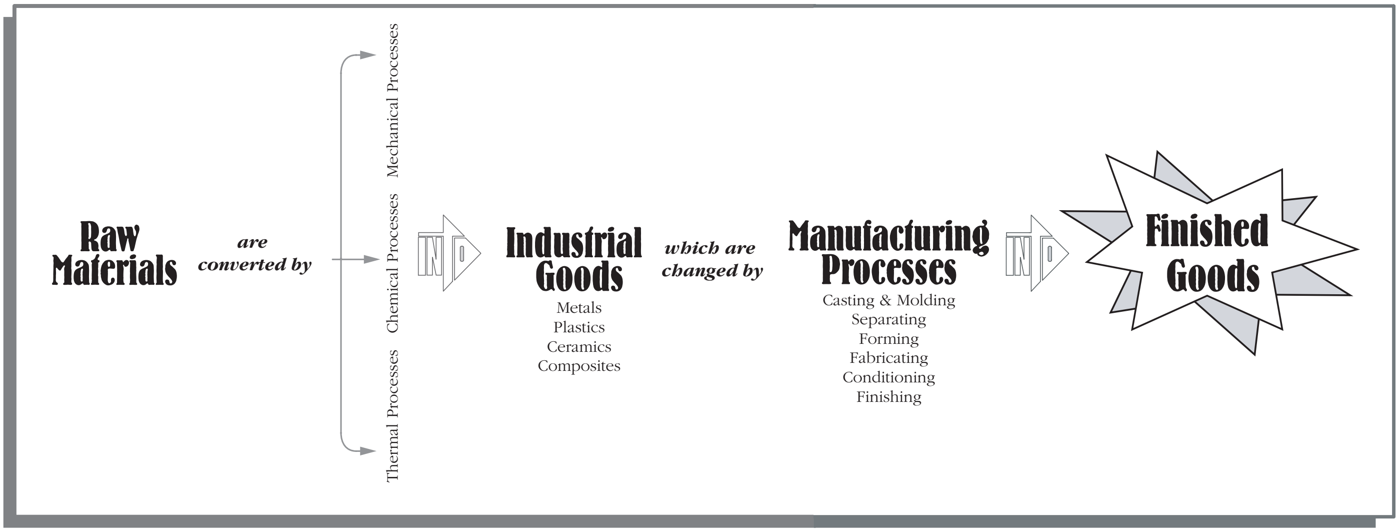
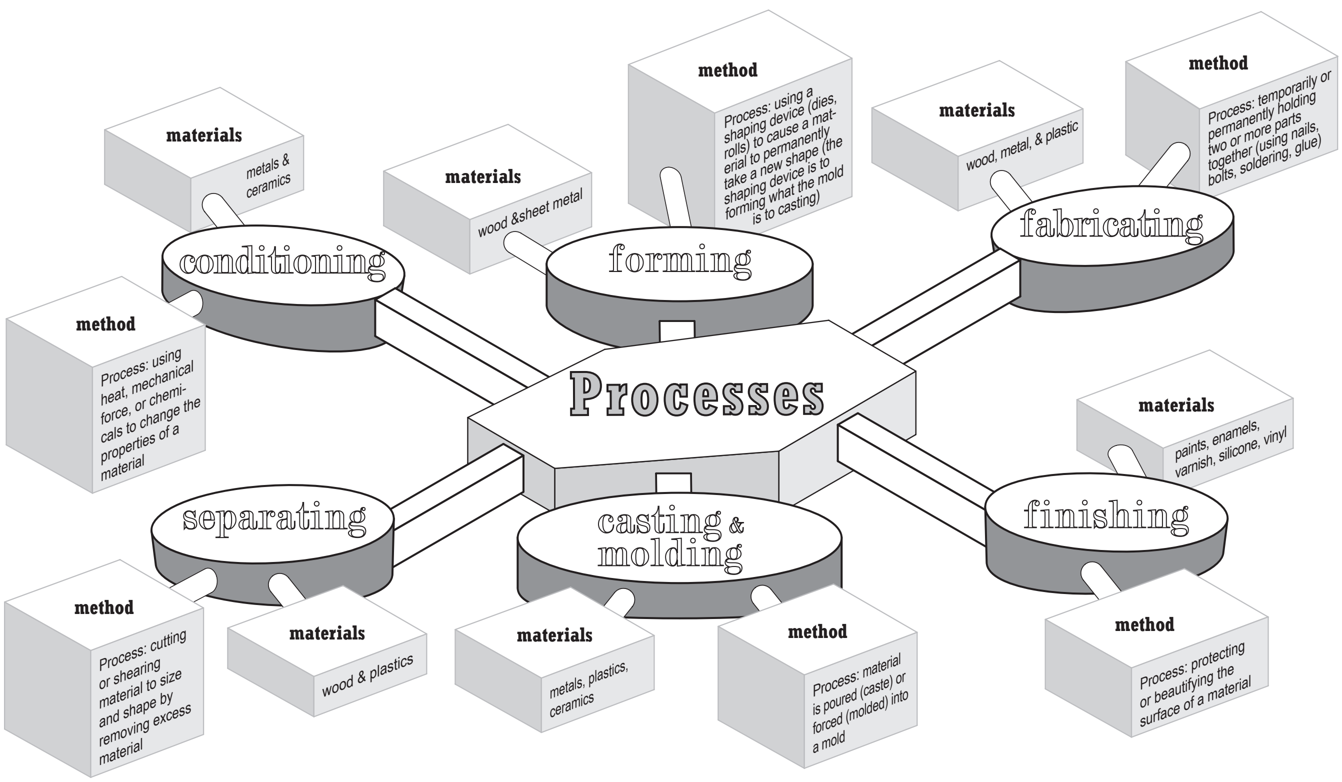


Figure 1. Manufacturing families



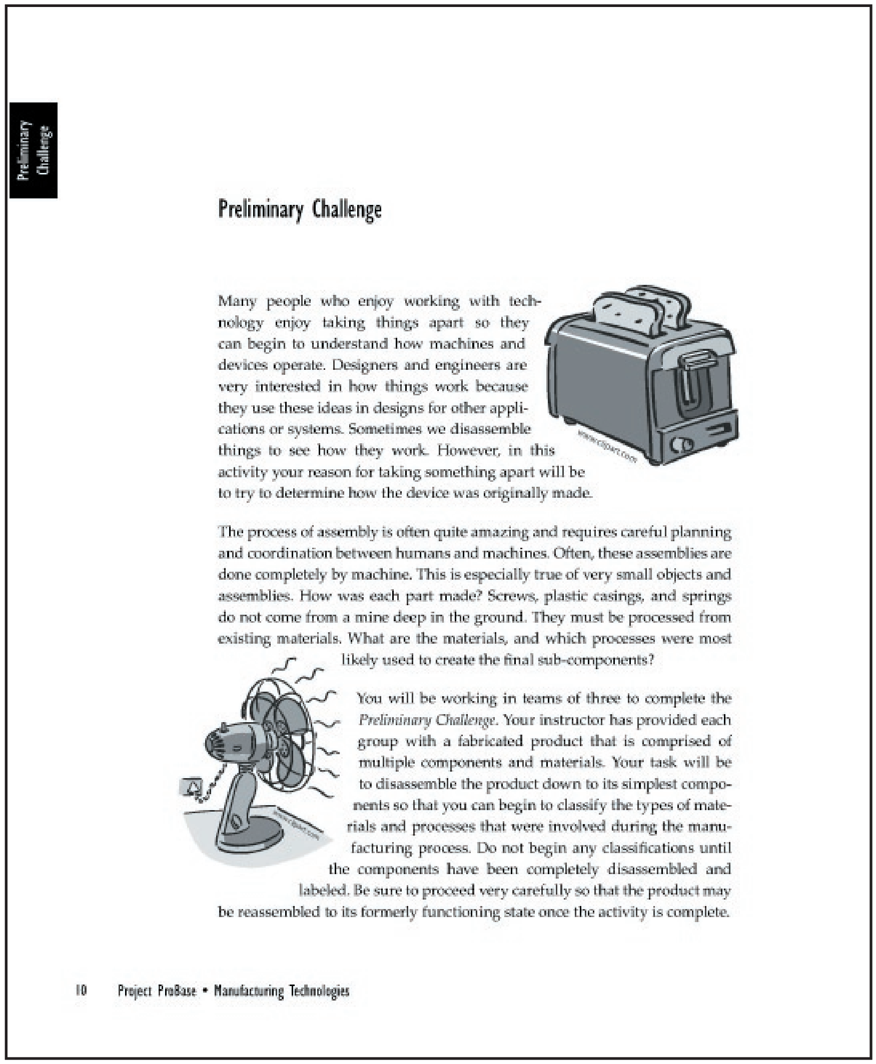

Raw Materials
are converted by
Thermal Processes
Chemical Processes
Mechanical Processes
Industrial Goods
Metals
Plastics
Ceramics
Composites
which are changed by
Manufacturing Processes
Casting & Molding
Separating
Forming
Fabricating
Conditioning
Finishing
Finished Goods


Processes
conditioning
materials
metals & ceramics
method
Process: using heat, mechanical force, or chemicals to change the properties of a material
forming
materials
wood &sheet metal
method
Process: using a shaping device (dies, rolls) to cause a material to permanently take a new shape (the shaping device is to forming what the mold is to casting)
fabricating
materials
wood, metal, & plastic
method
Process: temporarily or permanently holding two or more parts together (using nails, bolts, soldering, glue)
finishing
materials
paints, enamels, varnish, silicone, vinyl
method
Process: protecting or beautifying the surface of a material
casting & molding
materials
metals, plastics, ceramics
method
Process: material is poured (caste) or forced (molded) into a mold
separating
method
Process: cutting or shearing material to size and shape by removing excess material
materials
wood & plastics

Teaching Tips

The major goal of this *Preliminary Challenge* is to have students analyze and differentiate between materials and processes utilized to manufacture a variety of products. Provide a copy of the materials and processes worksheet to each student at the beginning of this activity and make sure that the directions are clear. It may be a good idea to have a product (that one of the teams will not be using) partially disassembled to use as an example. After introducing the unit to your students, provide them with time to disassemble their products and complete the materials and processes form.

Please remind students not to plug their product into any power outlet. Also, let them know that if their product was in working condition before disassembly that it should be in working condition after the activity.



Preliminary Challenge

Preliminary Challenge

Many people who enjoy working with technology enjoy taking things apart so they can begin to understand how machines and devices operate. Designers and engineers are very interested in how things work because they use these ideas in designs for other applications or systems. Sometimes we disassemble things to see how they work. However, in this activity your reason for taking something apart will be to try to determine how the device was originally made.

The process of assembly is often quite amazing and requires careful planning and coordination between humans and machines. Often, these assemblies are done completely by machine. This is especially true of very small objects and assemblies. How was each part made? Screws, plastic casings, and springs do not come from a mine deep in the ground. They must be processed from existing materials. What are the materials, and which processes were most likely used to create the final sub-components?

You will be working in teams of three to complete the *Preliminary Challenge*. Your instructor has provided each group with a fabricated product that is comprised of multiple components and materials. Your task will be to disassemble the product down to its simplest components so that you can begin to classify the types of materials and processes that were involved during the manufacturing process. Do not begin any classifications until the components have been completely disassembled and labeled. Be sure to proceed very carefully so that the product may be reassembled to its formerly functioning state once the activity is complete.

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Teaching Tips

When a component cannot be explored further you will need to help students make a decision about going further. Some plastic cases can be opened by cutting along the seam and can then be glued back together. Students should not break any sealed cases. You should encourage your students to explore the components as thoroughly as possible. Students may need to conduct research on the Internet or other resources to help them determine some of the processes used to manufacture their products.

Preliminary Challenge

If you reach a sub-component that is too intricate or that requires special tools during disassembly, your instructor should be consulted as to whether further disassembly should be conducted. While disassembling the object, be sure to place all fasteners and sub-components in a plastic tray or box so as to not lose materials that will be needed for reassembly after completing this *Preliminary Challenge*.

- Review the family of materials and the family of processes as a class to make sure that you understand what each of these categories should include.
- Begin disassembling your product and completing the "Material and Process Evaluation" table found on page 13.
- Come up with a name for each sub-component in your product and begin listing them in the vertical column of the table.
- As a team, begin discussing the material and process categories that each sub-component could be classified under and place a check under each applicable column. Some items may involve more than one process and may even contain multiple materials. Be prepared to discuss those exceptions with the rest of the class.

Family Ties 11

Teaching Tips

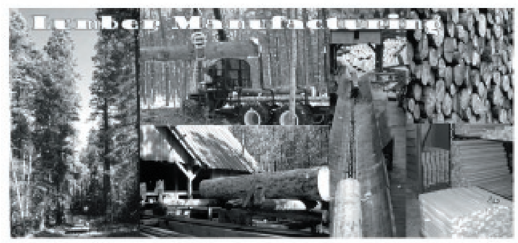
Please caution students not to break sealed cases with force as this may result in injury or irreparable harm to the device. After teams have completed this task, discuss their findings as a class to determine which materials and processes are more commonly used to manufacture the selected products.

Preliminary Challenge

Notes:

Preliminary Challenge

- As a team, provide an informal presentation of your findings to the rest of the class. Your presentation should focus on the following items: a brief description of each component, materials classification(s), and processes classification(s)
- After all of the teams have completed their presentations, reassemble your product and return all of your materials and tools to their appropriate locations.



Material & Process Evaluation

Complete the form by inserting and identifying the name of the sub-component in the correct column, placing a check mark in the appropriate "Material Family" column, and then briefly describing how the part was processed during manufacturing in the appropriate "Process Family" column or columns. You will need to add rows as necessary.

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Students are asked to complete the Materials and Process Evaluation form found on the following page. It is also a part of their Student Guide. Students should complete the form by inserting and identifying name of the subcomponent in the correct column, placing a check mark in the appropriate "Material Family" column and then briefly describing how the part was processed during manufacturing in the appropriate "Process Family" column or columns.

Sub-Component	Material Family					Process Family					
	Metallic	Organic	Ceramic	Plastic	Composites	Casting & Molding	Finishing	Forming	Fabricating	Separating	Conditioning

Reflection

Students should be prepared to discuss those exceptions with the rest of the class. As a team, students must give an informal presentation of their findings to the rest of the class. Their presentation should focus on the following:

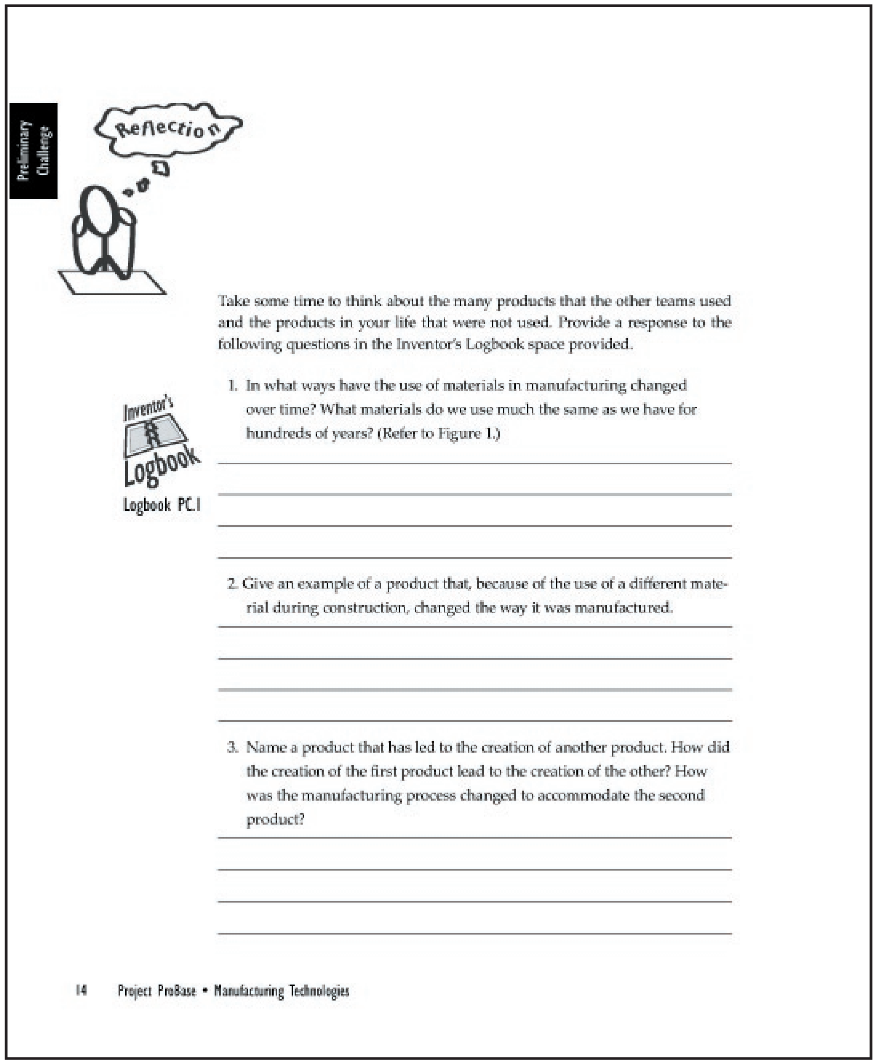
- Brief description of each component
- Materials classification(s)
- Processes classification(s)

After all of the teams have completed their presentations, they should reassemble their product and return all of their materials and tools to their appropriate location.

In the Inventor's Logbook space, students need to take some time to think about the many products that the other teams used as well as the products they see/use on a daily basis that may not have been selected for this activity.

1. In what ways have the use of materials in manufacturing changed over time? What material do we use much the same as we have for hundreds of years? (Refer back to Figure 1.)

   Answers will vary.


Preliminary Challenge

Reflection

Take some time to think about the many products that the other teams used and the products in your life that were not used. Provide a response to the following questions in the Inventor's Logbook space provided.

Inventor's Logbook

Logbook PC.1

1. In what ways have the use of materials in manufacturing changed over time? What materials do we use much the same as we have for hundreds of years? (Refer to Figure 1.)

2. Give an example of a product that, because of the use of a different material during construction, changed the way it was manufactured.

3. Name a product that has led to the creation of another product. How did the creation of the first product lead to the creation of the other? How was the manufacturing process changed to accommodate the second product?

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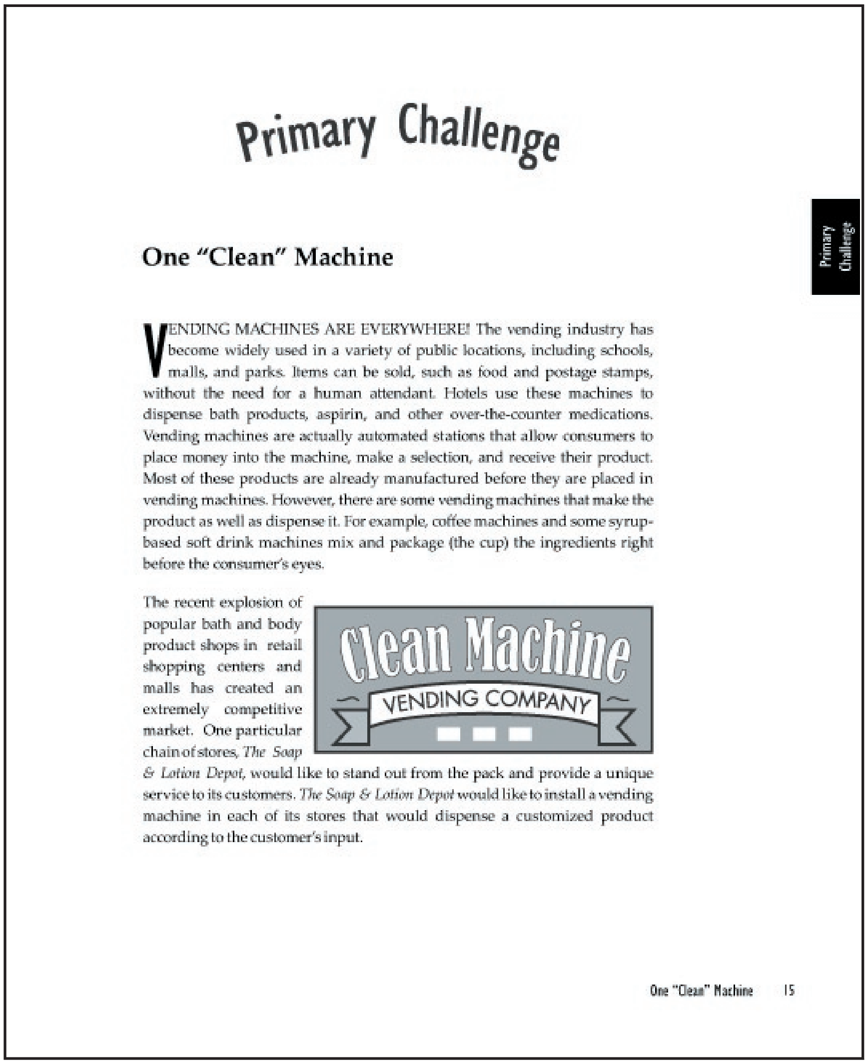
2. Give an example of a product that, because of the use of a different material in its construction, changed the way it was manufactured.

   Answers will vary.

3. Name one product that led to the creation of another (2nd) product. How did the creation of the first product lead to the creation of the other? How was the manufacturing process changed to accommodate the development of the second product?

   Answers will vary.



Primary Challenge

Primary Challenge

One "Clean" Machine

VENDING MACHINES ARE EVERYWHERE! The vending industry has become widely used in a variety of public locations, including schools, malls, and parks. Items can be sold, such as food and postage stamps, without the need for a human attendant. Hotels use these machines to dispense bath products, aspirin, and other over-the-counter medications. Vending machines are actually automated stations that allow consumers to place money into the machine, make a selection, and receive their product. Most of these products are already manufactured before they are placed in vending machines. However, there are some vending machines that make the product as well as dispense it. For example, coffee machines and some syrup-based soft drink machines mix and package (the cup) the ingredients right before the consumer's eyes.

The recent explosion of popular bath and body product shops in retail shopping centers and malls has created an extremely competitive market. One particular chain of stores, *The Soap & Lotion Depot*, would like to stand out from the pack and provide a unique service to its customers. *The Soap & Lotion Depot* would like to install a vending machine in each of its stores that would dispense a customized product according to the customer's input.

Clean Machine

VENDING COMPANY

One "Clean" Machine 15

One "Clean" Machine

Introduction

The *Primary Challenge* should be introduced immediately after students complete the *Preliminary Challenge* so that they can begin to relate concepts taken from the learning cycles back to the *Primary Challenge* during the remainder of the nine-week period.

Estimated Number of 50 minute class periods: **12** *(throughout the unit & at the end of the learning cycles)*

Facility Requirements

The *Primary Challenge* can be completed in a regular classroom setting. However, you may want to lay plastic down on the floors to prevent damage caused by soap leaking from students' solutions.

Equipment and Materials

Based on a class of 28 students divided into four-person teams:

The following is a basic list for each group. Materials and equipment will vary according to the sensors or requirements or functions students select for their soap dispensing device. When ordering sensors, switches, actuators, etc., be sure to order compatible components.

cont'd on following page

Primary Challenge

(7) BASIC Stamp® HomeWork Boards™

Electronic components (resistors, capacitors, etc.) for HomeWork Board

(7) Servo motors

Variety of sensor and switches (push-button, float switch, etc.)

(7) Relays

Gallon liquid hand soap (unscented), possible source: www.chemistrystore.com

(3) Soap colors, possible source: www.chemistrystore.com

(3) Soap scents, possible source: www.chemistrystore.com

(12) Empty film canisters or suitable containers for liquid soap

Rubber/plastic tubing

Miscellaneous materials (wood, nails, etc.)

Suggested resource site for materials:

Valves, connectors, tubing:
www.usplastics.com

As you gain experience with this unit, you may want to add additional sensors, motors, controls, etc. Please encourage students to design and construct their own solution to this challenge.

Primary Challenge

Specifically, the chain wants a vending machine that would dispense a bottle of liquid soap with a monogrammed label after customers input their first name and select their favorite color and scent. *The Soap & Lotion Depot* believes that by offering a customized product, it will be able to corner more of the bath and body product market. The company believes the machine will not only satisfy current customers' desires for receiving a customized product on demand, but will also draw new customers to its stores.

The chain is so excited about the prospect of incorporating the vending machine into its stores that it has asked you to "prove the concept." In order to prove the concept, you will need to develop a prototype of a vending machine that will serve all of *The Soap & Lotion Depot*'s needs. The machine will need to incorporate some degree of automation with sensors, relays, and a microprocessor to control the input and output. Besides the creation of the customized product, the chain is also very concerned with the machine's appearance. The machine should be as attractive and as compact as possible so it will draw customers' attention and so it can be moved around the store easily. Keeping all of these factors in mind, your task is to design a machine that will meet *The Soap & Lotion Depot*'s demands of form and function.

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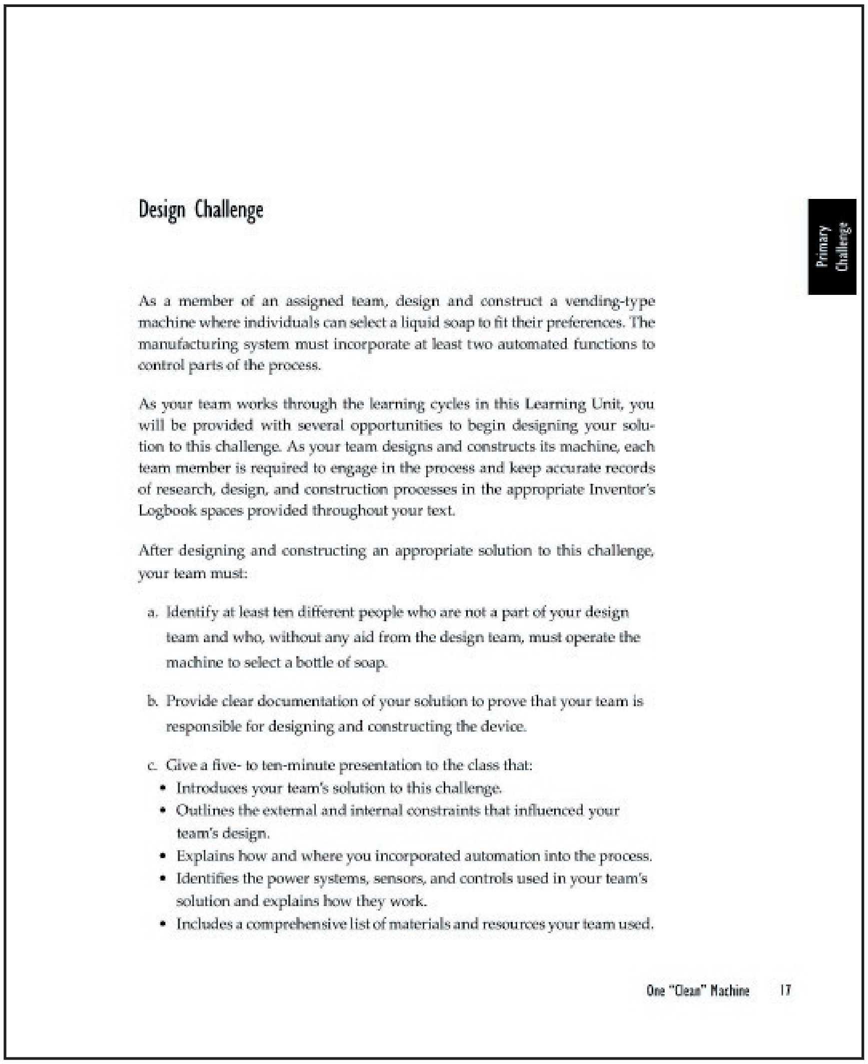
Teaching Tips

You may want to bring in various examples of liquid soaps. (For example, dish soap, different colored soaps and fragrances, glitter soap, and antibacterial soap.)



Design Challenge

Primary Challenge

As a member of an assigned team, design and construct a vending-type machine where individuals can select a liquid soap to fit their preferences. The manufacturing system must incorporate at least two automated functions to control parts of the process.

As your team works through the learning cycles in this Learning Unit, you will be provided with several opportunities to begin designing your solution to this challenge. As your team designs and constructs its machine, each team member is required to engage in the process and keep accurate records of research, design, and construction processes in the appropriate Inventor's Logbook spaces provided throughout your text.

After designing and constructing an appropriate solution to this challenge, your team must:

a. Identify at least ten different people who are not a part of your design team and who, without any aid from the design team, must operate the machine to select a bottle of soap.

b. Provide clear documentation of your solution to prove that your team is responsible for designing and constructing the device.

c. Give a five- to ten-minute presentation to the class that:
- Introduces your team's solution to this challenge.
- Outlines the external and internal constraints that influenced your team's design.
- Explains how and where you incorporated automation into the process.
- Identifies the power systems, sensors, and controls used in your team's solution and explains how they work.
- Includes a comprehensive list of materials and resources your team used.

One "Clean" Machine 17

Constraints and Requirements

Be sure to remind students of the design constraints for the challenge. The designed solution must:

- Produce a bottle of liquid soap safely with controls that are explanatory and intuitive for the intended consumer(s).
- Use at least two sensors (e.g., light, sound, heat, etc.) in the system.
- Provide for some type of user control or interface that allows the customer to choose from three 3 different soap colors and/or scent combinations as well as labeling customization.
- Use raw materials for soap that are safe to handle, affordable, and require the least amount of processing time and energy.
- Be designed and constructed to be mobile, self-contained, attractive, and intuitive for the customer.
- Be designed in such a way as to limit the amount of materials (liquids) spilled inside the machine.
- Ensure safety to the operating customer.
- Be accompanied with documentation, computer-aided drawings, flow charts, and Inventor's Logbook entries that provide evidence of an original design.

Primary Challenge

Teaching Tips

When students are initially testing their soap dispensing designs, you may want to have them substitute water for soap. This will help reduce messy soap spills. You may also want to discuss the viscosity of liquids and how their designs may function differently with the soap versus the water.

Design Challenge

After constructing their soap dispensing machine, each team must:

a. Identify at least ten different people who are not a part of the design team to operate the machine without aid from any member of the design team. This will allow the designers an opportunity to determine whether the machine is truly intuitive and functional in a machine-to-human interaction format.

b. Provide clear documentation of the solution to prove that their team is responsible for designing and constructing the device.

Constraints/Requirements

The designed solution must:

- Produce a bottle of liquid soap safely with controls that are explanatory and intuitive for the intended consumer(s).
- Use at least two sensors (e.g., light, sound, heat) in the system.
- Provide for some type of user control or interface that allows the customer to choose from three different soap colors and/or scent combinations, as well as labeling customization.
- Use raw materials for soap that are safe to handle, affordable, and require the least amount of processing time and energy.
- Be designed and constructed to be mobile, self-contained, attractive, and intuitive for the customer.
- Be designed in such a way as to limit the amount of materials (liquids) spilled inside the machine.
- Ensure safety to the operating customer.
- Be accompanied with documentation, computer-aided drawings, flow charts, and Inventor's Logbook entries that provide evidence of an original design.

c. Give a five- to ten-minute presentation to the class that:

- Introduces their team's solution to this challenge.
- Outlines the external and internal constraints that influenced their team's design.
- Explains how and where they incorporated automation into the process.
- Identifies the power systems, sensors, and controls that are used in their team's solution and explains how they work.
- Includes a comprehensive list of materials and resources their team used.

Teaching Tips

You may decide to assign each team member a role throughout the duration of the *Primary Challenge*. Each member will be responsible for executing the specific constraints and requirements of the *Primary Challenge* and duties described by their role.

For example, you may assign roles that include a designer, marketing manager, finance manager, and ergonomics/safety/environment engineer. A document is included in the appendix on page AI that can be replicated for each team. The document has the team roles broken down and space to list the responsibilities of each role.

Teaching Tips

As a constructivist-based Learning Unit, it is important to focus on conceptual development. Therefore, it will be important for your class to stop and check for understanding from time to time throughout this unit. The students' Inventor's Logbook will serve as one means to check student progress on a regular basis. Here are a few other strategies that may help you keep your students focused on their conceptual development.

- Create a large poster with the key concepts and/or enduring understandings and place it in a prominent spot in your classroom (An example layout can be found in the Appendix).
- Break students into their *Primary Challenge* teams and identify what they know and what they need to know to solve the *Primary Challenge*. Compile their thoughts through a discussion and create a large class display of what they know and what they need to know. Require the students to "check off" the questions that have been answered during the course of the Learning Unit.
- Have your students create concept maps of the unit in their Inventor's Logbook.

Questions about the *Primary Challenge* should be addressed. However, no work on the actual *Primary Challenge* should take place at this time. There will be approximately two weeks to complete the *Primary Challenge.* Students will reflect on the upcoming *Primary Challenge* throughout the learning cycles to relate what they have learned with what will be needed to solve the problem presented.

Preparing for the Primary Challenge

After going through the *Preliminary Challenge* and explaining the *Primary Challenge*, you will need to divide your class into teams. These teams will be working together to solve the *Primary Challenge*.

Student Assessment

A rubric has been placed on the following page. Based upon your situation, please feel free to modify the scoring guidelines. The rubric should be discussed and shared with your students, focusing on the necessary requirements for the *Primary Challenge*.

Teaching Tips

You may want to take your class on a tour of a vending machine company or ask a technician to open a vending machine and discuss how the machine dispenses soda or another product.

Primary Challenge Rubric

Element	Criteria				Points
Point Values	40	30	20	10	
Primary Challenge Product	Completed product is fully functional and addresses all criteria, parameters, and equipment specifications set forth in the *Primary Challenge.*	Completed product is functional and meets most criteria, parameters, and equipment specifications set forth in the *Primary Challenge.*	Completed product represents a serious attempt to solve the primary challenge but does not address many of the stated criteria, parameters, or specifications.	Product is not complete or does not function well and does not meet stated criteria, parameters, or specifications.	
				Sub-total	
Point Values	15	10	5	2	
Drawings, Diagrams & Sketches	Drawings, diagrams, or sketches clearly illustrate an understanding of all requirements, criteria, or specifications, uses proper format, and was completed electronically.	Drawings, diagrams, or sketches illustrate needed information, but do not address all stated requirements, criteria, or specifications. Completed using an electronic format.	Drawings, diagrams, or sketches illustrate needed information, but do not address all stated requirements, criteria, or specifications. Did not utilize an electronic format (hand drawn).	Drawings, diagrams, or sketches do not illustrate all needed information. Illustrations are incomplete or poorly presented.	
Research & Development	Clear evidence of a comprehensive research and development effort was provided and ten people successfully tested the solution.	Research and development was conducted while solving the *Primary Challenge*, but documentation was marginal.	Some research and development techniques were used while attempting to solve the *Primary Challenge*, but were not clearly documented.	Minimal research and development techniques were used while attempting to solve the *Primary Challenge*. Documentation was marginal.	
Documentation	As directed, the team responded to questions and/or maintained comprehensive records, logs, and other notations of activities while completing the *Primary Challenge*.	Team responded to questions and/or maintained topical records, logs, and other notations of activities while completing the *Primary Challenge*.	Team responded to most questions and/or maintained some records, logs, and other notations of activities while completing the *Primary Challenge*.	Team marginally responded to questions and did not maintain records, logs, and other notations of activities while completing the *Primary Challenge*.	
Presentation	Presentation demonstrates a full grasp of the major concepts, addresses all stated presentation requirements, and conforms to time limit constraints.	Presentation demonstrates significant understanding of major concepts, addresses most presentation requirements, and conforms to time limitations.	Presentation topically addresses some of the concepts delivered in this unit, but does not conform to stated presentation guidelines and/or time limits.	Presentation does not demonstrate a grasp of the major concepts delivered in this unit and/or does not address stated presentation guidelines or time limits.	
				Total Points	

Learning Cycle One

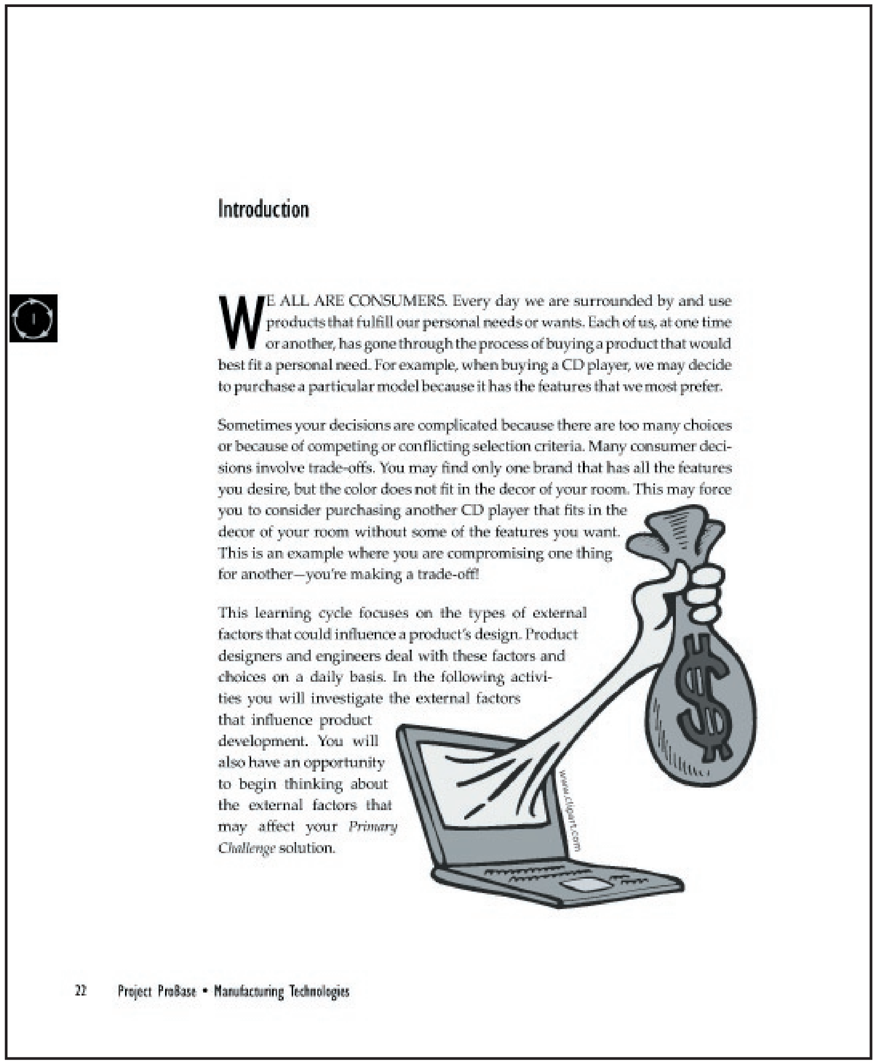
Under Pressure

Under Pressure

Introduction

The goal for the *Exploration* phase is to expose students to how customer, societal, and environmental concerns affect the design of products. Students will examine a Lunchable® Box and identify the customer needs/wants the product was intended to fulfill. In addition, students are asked to identify the product from which the Lunchable® is a spinoff. In the second task, students will examine and evaluate products for societal and environmental influences. Applying what they have just learned, students will then explore their choice of liquid soap container and soap preferences to be included in their solution to the *Primary Challenge.*

In the *Engagement* section, students will identify personal factors that influence their decisions when they make soap purchases and the factors that they need to consider when designing a solution to the *Primary Challenge.*



Introduction

WE ALL ARE CONSUMERS. Every day we are surrounded by and use products that fulfill our personal needs or wants. Each of us, at one time or another, has gone through the process of buying a product that would best fit a personal need. For example, when buying a CD player, we may decide to purchase a particular model because it has the features that we most prefer.

Sometimes your decisions are complicated because there are too many choices or because of competing or conflicting selection criteria. Many consumer decisions involve trade-offs. You may find only one brand that has all the features you desire, but the color does not fit in the decor of your room. This may force you to consider purchasing another CD player that fits in the decor of your room without some of the features you want. This is an example where you are compromising one thing for another—you're making a trade-off!

This learning cycle focuses on the types of external factors that could influence a product's design. Product designers and engineers deal with these factors and choices on a daily basis. In the following activities you will investigate the external factors that influence product development. You will also have an opportunity to begin thinking about the external factors that may affect your *Primary Challenge* solution.

www.clipart.com

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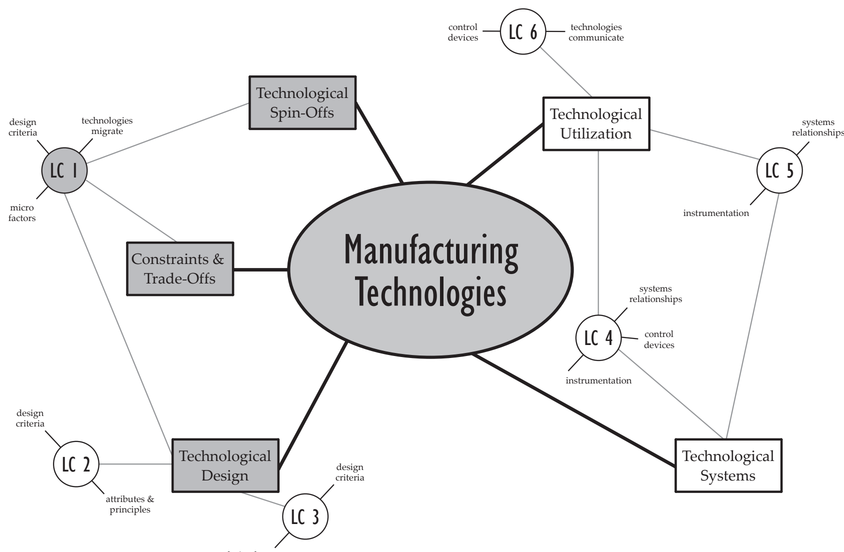
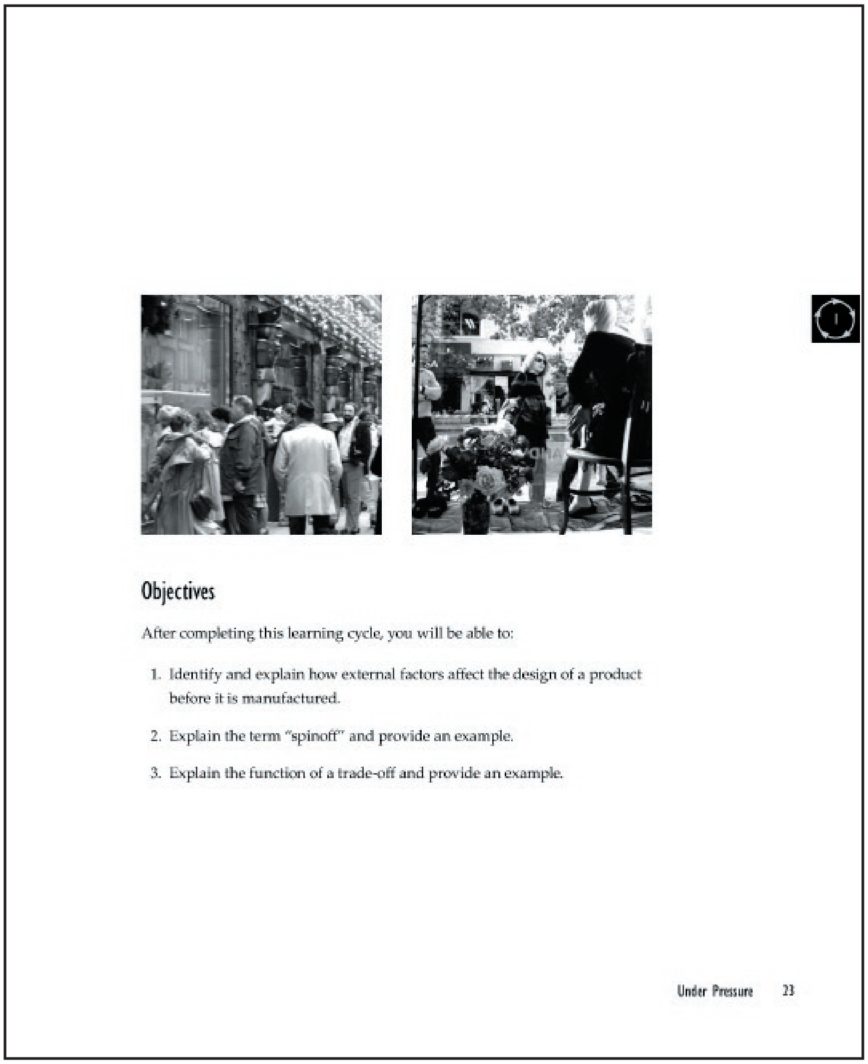
Manufacturing Technologies
Learning Cycle One Concept Map





Objectives

After completing this learning cycle, you will be able to:

1. Identify and explain how external factors affect the design of a product before it is manufactured.
2. Explain the term "spinoff" and provide an example.
3. Explain the function of a trade-off and provide an example.

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Objectives and Essential Questions

After completing this learning cycle, students will be able to:

1. Identify and explain how external factors affect the design of a product before it is manufactured.
Essential Question 7c: What design criteria is typically considered when developing new technologies and how do these influence the final product or system's design?

2. Identify and explain what a spinoff is.
Essential Question 2a: How do technologies migrate from one context (or location) to another and what are the implications?

3. Identify and explain the function of a trade-off.
Essential Question 6b: What are the key factors that cause designers to make decisions about trade-offs, limitations, and constraints when designing new products and systems?

Facility Requirements

This learning cycle can be completed in a regular classroom. Specific equipment is not needed.

Equipment and Materials

Based on a class of 28 students:

(7) Oscar Mayer Lunchables® (or other brands)

(21) Bars of soap. You will need to purchase three distinctly different types of soap for each team. The soap should represent name brands as well as generic brands. Be sure to purchase enough bars so that each team of 4-5 students can observe different textures, colors, and scents.

(7) Product box – box should be filled with various types of household products

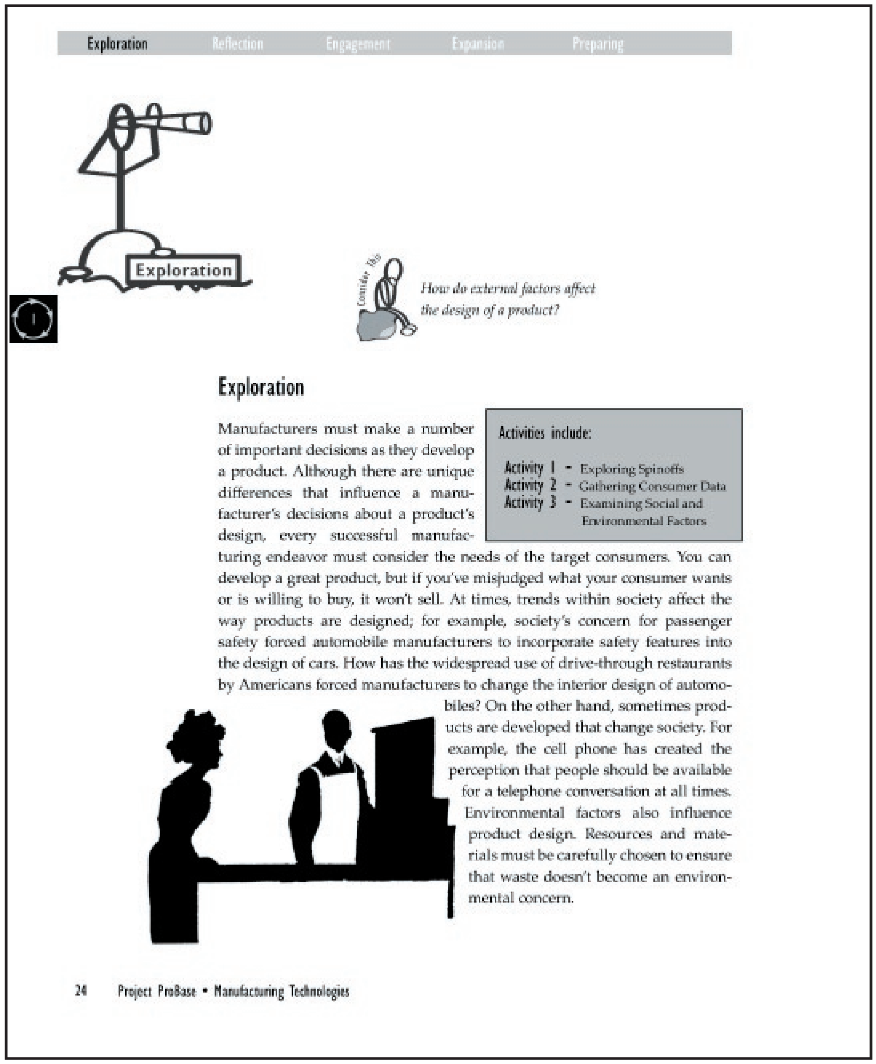
(7) Pads of flip chart paper

(7) Markers

Estimated number of 50-minute class periods: **5**

Suggested Daily Outline

Day One	Day Two
Exploration Exploring Spinoffs and Customer Data	*Exploration* cont., Societal and Environmental Factors *Reflection*
Day Three	**Day Four**
Engagement Customer Survey	*Engagement* Survey analysis
Day Five	
Preparing for the Challenge	


Exploration Reflection Engagement Expansion Preparing

Exploration

Consider This

How do external factors affect the design of a product?

Exploration

Manufacturers must make a number of important decisions as they develop a product. Although there are unique differences that influence a manufacturer's decisions about a product's design, every successful manufacturing endeavor must consider the needs of the target consumers. You can develop a great product, but if you've misjudged what your consumer wants or is willing to buy, it won't sell. At times, trends within society affect the way products are designed; for example, society's concern for passenger safety forced automobile manufacturers to incorporate safety features into the design of cars. How has the widespread use of drive-through restaurants by Americans forced manufacturers to change the interior design of automobiles? On the other hand, sometimes products are developed that change society. For example, the cell phone has created the perception that people should be available for a telephone conversation at all times. Environmental factors also influence product design. Resources and materials must be carefully chosen to ensure that waste doesn't become an environmental concern.

Activities include:

Activity 1 - Exploring Spinoffs
Activity 2 - Gathering Consumer Data
Activity 3 - Examining Social and Environmental Factors

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Exploration

Exploring Spinoffs

Teaching Tips

Students will be examining an Oscar Mayer Lunchable® box or similar product. You will need to make sure that you have enough Lunchables® so that each group has its own box.

Exploration Reflection Engagement Expansion Preparing

Exploring SpinOffs

Most of the time materials, products, or processes are developed for specific purposes. However, sometimes the materials, products, or processes developed for a specific purpose are applied to meet a need in a different situation or context. For example, in the early 1970s an inorganic zinc-silicate coating material called IC-531 was developed at NASA's Goddard Space Flight Center. NASA developed this material to protect the launch structures at Kennedy Space Center from salt corrosion, rocket exhaust, and thermal shock. More than a decade later, IC-531 turned out to be the perfect coating to protect the interior structure of the Statue of Liberty and prolong the statue's life. This coating material has also been used to protect the Columbia River Bridge, as well as power transmission stations used by power utility companies.

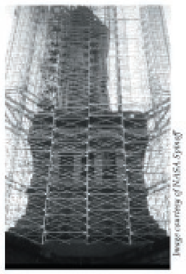


Image courtesy of NASA Spinoff

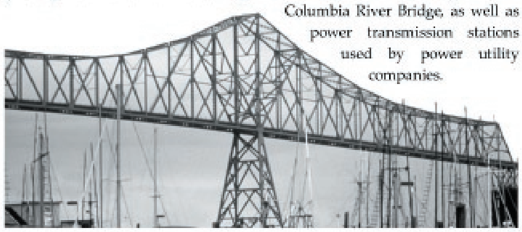


Image courtesy of NASA Spinoff

Under Pressure 25

Teaching Tips

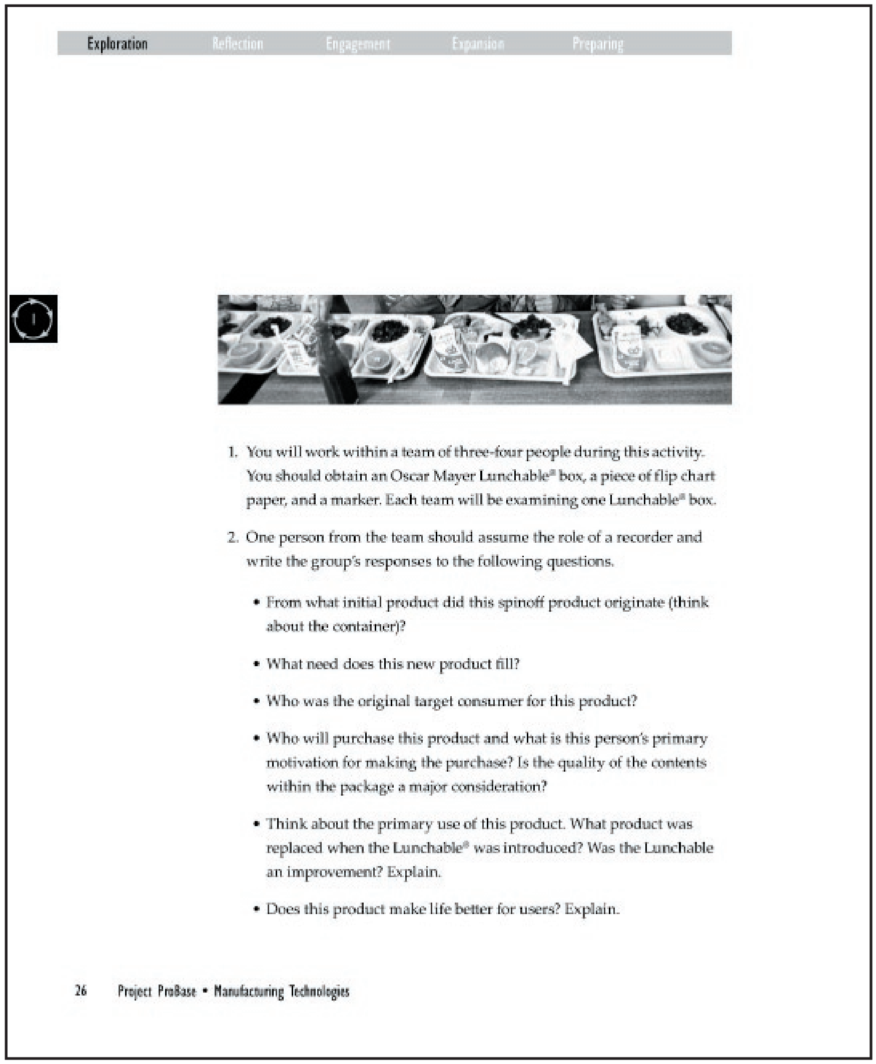
Students are required to answer the following questions:

- From what product did this spinoff product originate (think about the container)?
- What need does this new product fill?
- Who was the original target customer for the product?
- Who will purchase this product and what is this person's primary motivation for making the purchase? Is the quality of the contents a major consideration?
- What product was replaced when the Lunchable® was introduced? Was the Lunchable® an improvement?
- Does this product make life better for users? Explain.

After the students have had a chance to answer the above questions, initiate a class discussion to discuss answers. Lunchables® are a spinoff idea from the U.S. Army's Meals Ready To Eat (MRE's) program and early TV dinners. Students should have a clear understanding of what a spinoff is by the end of this task.

It would be a good idea to have other examples of spinoffs on hand. Possible examples include:

- Infrared thermometers (developed to detect energy from stars and planets)
- Smoke detectors (developed for Skylab)
- Cordless power tools (developed for the Apollo program so that astronauts could drill core samples from the moon)
- Kevlar (originally developed to replace the steel found in radial tires)



Exploration Reflection Engagement Expansion Preparing

1. You will work within a team of three-four people during this activity. You should obtain an Oscar Mayer Lunchable® box, a piece of flip chart paper, and a marker. Each team will be examining one Lunchable® box.
2. One person from the team should assume the role of a recorder and write the group's responses to the following questions.
   - From what initial product did this spinoff product originate (think about the container)?
   - What need does this new product fill?
   - Who was the original target consumer for this product?
   - Who will purchase this product and what is this person's primary motivation for making the purchase? Is the quality of the contents within the package a major consideration?
   - Think about the primary use of this product. What product was replaced when the Lunchable® was introduced? Was the Lunchable an improvement? Explain.
   - Does this product make life better for users? Explain.

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Teaching Tips

Students are asked to design a Lunchable® box that can be used by adults in a business environment. You will not have sufficient time to allow them to build the "adult Lunchable®" in class. You can either assign this as homework or have them illustrate their ideas on a piece of flow chart paper and share their ideas with the class.

3. After the team has responded to the above questions, your teacher will organize a class discussion, during which each team will share team answers (to the above questions) with the entire class.

While continuing to consider the Lunchable® example, consider the following scenario. If you were asked to redesign the Lunchable® to attract the attention of business people, what changes or additions would you make to the product? If the Lunchable® were to be used during business luncheons, how would the product need to change? If you were the product design team working on this project, how would the team members determine what should be included in the "Business Lunchable" product? On a large piece of flip chart paper, create a flip chart that identifies the steps needed to identify your consumer needs and then consider the information on the following pages.

Spinoffs

Notes:

Exploration | Reflection | Engagement | Expansion | Preparing

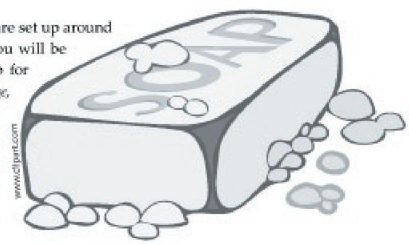
Consumer Data

Before a manufacturer designs a product, the needs of the consumer must be identified. Identifying the needs of your target consumer is crucial for a product's success. The following three-step process can be used to learn more about your consumers' needs:

1. Collect information from consumers (market research).
2. Transform the information into consumer needs.
3. Organize the needs into order of importance to the consumer.

New products and innovations are often the result of a company staying in touch with consumer needs. By staying in touch with the criteria consumers use to purchase a particular product, a manufacturer can develop products that are more competitive.

Several soap stations are set up around the class. Although you will be producing liquid soap for the *Primary Challenge*, you will be using bar soap for this activity. Many of the qualities of bar soap that you will be looking at can relate just as well to liquid soap.



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Customer Data

Teaching Tips

You will need to purchase three distinctly different types of soap. The soap should represent name brands as well as generic brands. Be sure to purchase enough bars so that each team of 4-5 students can observe different textures, colors, and scents.

Teaching Tips

Each group should get three different bars of soap to examine. The sub-tasks under this task section may not take that long, but make sure the students enter the required data in the Inventor's Logbook spaces provided in the Student Guide.

Exploration Reflection Engagement Expansion Preparing

The stations are set up so you can explore soap samples from a variety of sources that represent national name brands as well as generic brands. At your assigned station, your team will investigate the quality differences between the soap brands with regards to smell, color, and texture. The final goal of this learning cycle is to collect enough data to make informed decisions as to what characteristics of soap are most preferred by potential consumers.

Collect the following data in your team and prepare to share your findings with the class so that conclusions can be made about soap preferences.

Each member of your team should smell the fragrance, study the color, and examine the texture of each soap sample and record their preferences in Table 1 provided in the Inventor's Logbook space below.

	Smell	Color	Texture
Student A			
Student B			
Student C			
Student D			
Student E			
Student F			

Table 1. Soap preferences

Inventor's Logbook

Logbook 1.1

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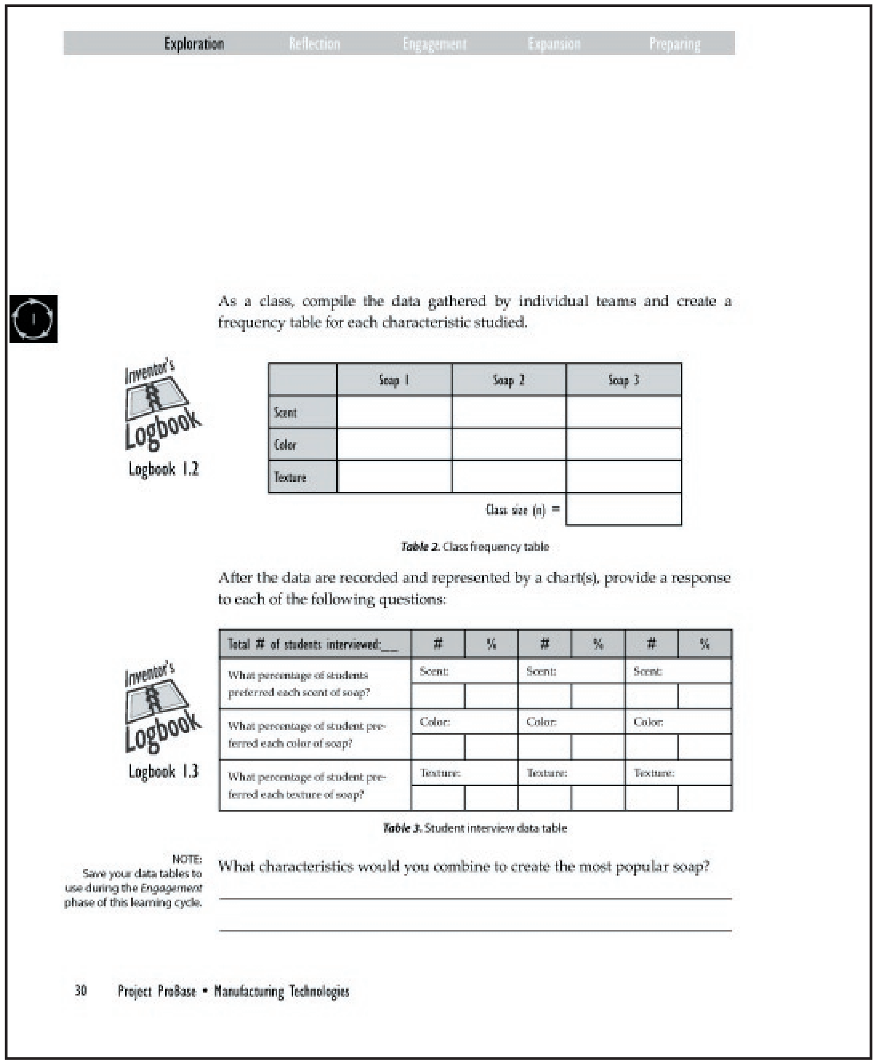
Teaching Tips

You may want to require students to create electronic spreadsheets to record the data they are asked to collect.

	Smell	Color	Texture
Student A			
Student B			
Student C			
Student D			
Student E			
Student F			

Table 1. Preferences for soap fragrance



Exploration Reflection Engagement Expansion Preparing

As a class, compile the data gathered by individual teams and create a frequency table for each characteristic studied.

Inventor's Logbook

Logbook 1.2

	Soap 1	Soap 2	Soap 3
Scent			
Color			
Texture			
		Class size (n) =	

Table 2. Class frequency table

After the data are recorded and represented by a chart(s), provide a response to each of the following questions:

Inventor's Logbook

Logbook 1.3

Total # of students interviewed:___	#	%	#	%	#	%
What percentage of students preferred each scent of soap?	Scent:		Scent:		Scent:	
What percentage of student preferred each color of soap?	Color:		Color:		Color:	
What percentage of student preferred each texture of soap?	Texture:		Texture:		Texture:	

Table 3. Student interview data table

NOTE: Save your data tables to use during the *Engagement* phase of this learning cycle.

What characteristics would you combine to create the most popular soap?

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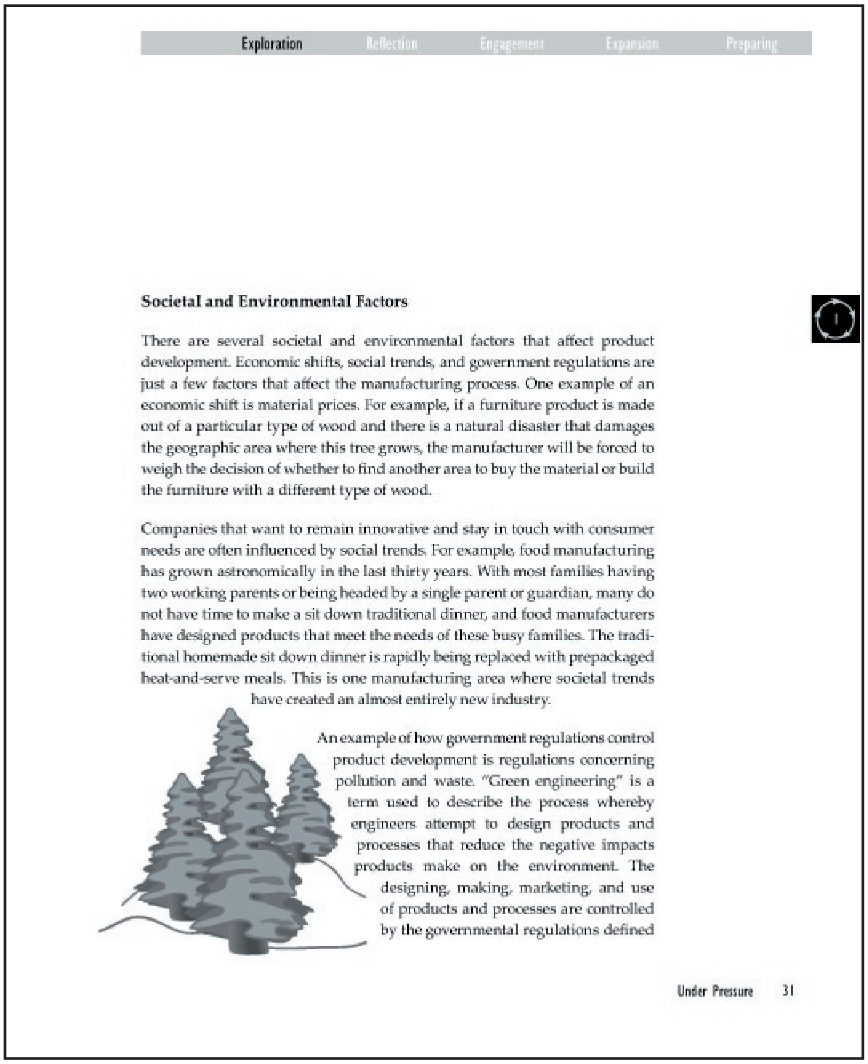
	Soap 1	Soap 2	Soap 3
Scent			
Color			
Texture			
		Class size (n) =	

Table 4. Class frequency table



Exploration Reflection Engagement Expansion Preparing

Societal and Environmental Factors

There are several societal and environmental factors that affect product development. Economic shifts, social trends, and government regulations are just a few factors that affect the manufacturing process. One example of an economic shift is material prices. For example, if a furniture product is made out of a particular type of wood and there is a natural disaster that damages the geographic area where this tree grows, the manufacturer will be forced to weigh the decision of whether to find another area to buy the material or build the furniture with a different type of wood.

Companies that want to remain innovative and stay in touch with consumer needs are often influenced by social trends. For example, food manufacturing has grown astronomically in the last thirty years. With most families having two working parents or being headed by a single parent or guardian, many do not have time to make a sit down traditional dinner, and food manufacturers have designed products that meet the needs of these busy families. The traditional homemade sit down dinner is rapidly being replaced with prepackaged heat-and-serve meals. This is one manufacturing area where societal trends have created an almost entirely new industry.

An example of how government regulations control product development is regulations concerning pollution and waste. "Green engineering" is a term used to describe the process whereby engineers attempt to design products and processes that reduce the negative impacts products make on the environment. The designing, making, marketing, and use of products and processes are controlled by the governmental regulations defined

Under Pressure 31

Students should be looking at the trade-off decisions that influenced the product and design of the package.

Societal and Environmental Factors

Teaching Tips

For this task, you need to collect empty product containers or other products that were influenced by society. Try to include a variety of soap, lotion, and shampoo containers. You may want to encourage the students to bring in products that they use from home. Some examples include:

- Disposable diapers
- Cell phones
- Gaming system such as PS or PS2
- Fast food containers, plastic silverware
- DVDs or any portable device

Have the students meet in their *Primary Challenge* groups and divide the containers among them. Soap containers should be given to each group.

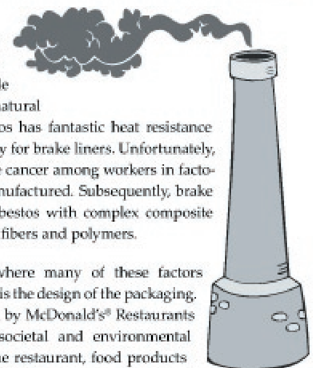
Total # of students interviewed:___	#	%	#	%	#	%
What percentage of students preferred each scent of soap?	Scent:		Scent:		Scent:	
What percentage of students preferred each color of soap?	Color:		Color:		Color:	
What percentage of students preferred each texture of soap?	Texture:		Texture:		Texture:	

Teaching Tips

One example of a trade-off might include something as simple as risking having the contents of a locker stolen by presetting the lock combinations to save a few seconds during a passing period. A more complex example includes choosing what type of lawn mower to purchase. One could decide to buy a power mower or a non-motorized reel-type mower. The gas powered mower can cut faster through longer grass, but creates noise and air pollution. Purchasing an automobile provides another example where trade-offs are considered, such as gas mileage vs. speed or comfort vs. style.

Exploration Reflection Engagement Expansion Preparing

by the Environmental Protection Agency. Some companies may be forced to use materials or processes that affect the design of the product in order to stay within government mandated guidelines. For example, one material may be the most desired material to use for the best quality, but the waste from the production line may not be environmentally friendly. At the early stages of developing a process or product it is extremely important for engineers to consider human health and the environment in order for the product and production to be cost effective.



A good example of this is asbestos brake liners for automobiles. For many years, automobile brake liners were made from a natural material called asbestos. Asbestos has fantastic heat resistance qualities–a very important quality for brake liners. Unfortunately, asbestos has also proven to cause cancer among workers in factories where brake liners were manufactured. Subsequently, brake manufacturers have replaced asbestos with complex composite materials made from a variety of fibers and polymers.

An aspect of manufacturing where many of these factors combine to influence the product is the design of the packaging. For example, the packaging used by McDonald's® Restaurants has been influenced by both societal and environmental factors. Early in the history of the restaurant, food products were packaged using paper. In 1975 the company introduced a foam polystyrene package because of its superior insulating qualities. But by the 1980s the use of polystyrene was highly criticized by consumers for its threat to the environment. By 1990 McDonald's® had discontinued its use and introduced a corrugated container made from recycled paper.

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Teaching Tips

At this point students should understand what a trade-off is; however, you may want to provide examples to reinforce the concept.

Exploration Reflection Engagement Expansion Preparing

Although many scientists now suggest that polystyrene packaging causes no more environmental damage than paper or card stock, societal and environmental concerns caused McDonald's® to reassess its packaging and assure the public of its efforts to be environmentally sensitive.

In this activity, you will meet with your *Primary Challenge* group and explore different products and discuss the factors that may have influenced the design of the product's packaging.

1. Obtain at least three different product packages from your instructor.
2. Identify how each product is packaged (both in the manufacturing process and the materials used).

____

____

____

Inventor's Logbook

Logbook 1.4

3. Identify which societal factors may have influenced the product design. How has the packaging for this type of product changed over the years?

____

____

____

____

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Notes:

Notes:

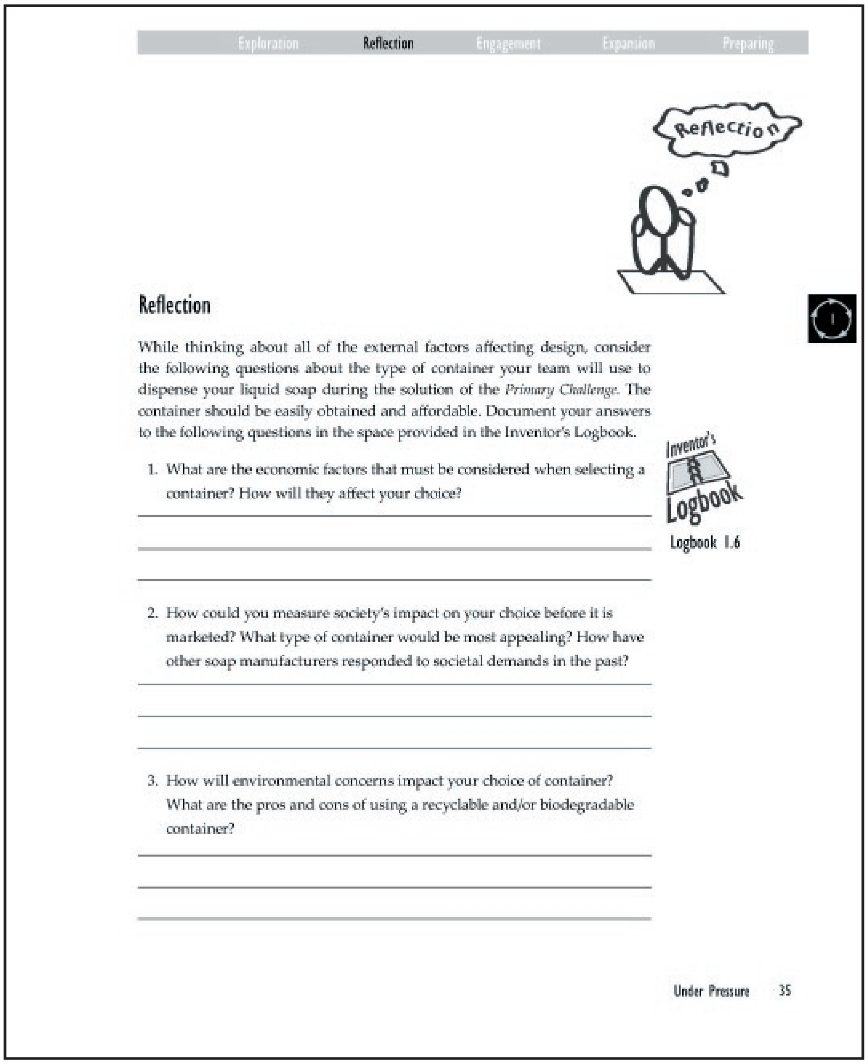
4. In the Inventor's Logbook space provided, create a table that lists the product, the societal influences, the environmental influences, and the resulting packaging changes during the life of the product.

Inventor's Logbook

Logbook 1.5

Figure 4. Product box

5. Can you find patterns in the table that you created in number four? Are there groups of similar products with similar purposes, functions, or processes? Do you think some products are influenced to a greater degree by one societal or one environmental factor than others?



Exploration Reflection Engagement Expansion Preparing

Reflection

While thinking about all of the external factors affecting design, consider the following questions about the type of container your team will use to dispense your liquid soap during the solution of the *Primary Challenge*. The container should be easily obtained and affordable. Document your answers to the following questions in the space provided in the Inventor's Logbook.

Logbook 1.6

1. What are the economic factors that must be considered when selecting a container? How will they affect your choice?

2. How could you measure society's impact on your choice before it is marketed? What type of container would be most appealing? How have other soap manufacturers responded to societal demands in the past?

3. How will environmental concerns impact your choice of container? What are the pros and cons of using a recyclable and/or biodegradable container?

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Reflection

Students should now have a good understanding of the three external factors that influence product design. At this point students should return to the *Primary Challenge* and answer the following questions in the spaces provided:

1. What are the economic factors that must be considered when selecting a container? How will they affect your choice?

2. How could you measure society's impact on your choice before it is marketed? What type of container would be most appealing? How have other soap manufacturers responded to societal demands in the past?

3. How will environmental concerns impact your choice of container? What are the pros and cons of using a recyclable and/or biodegradable container?

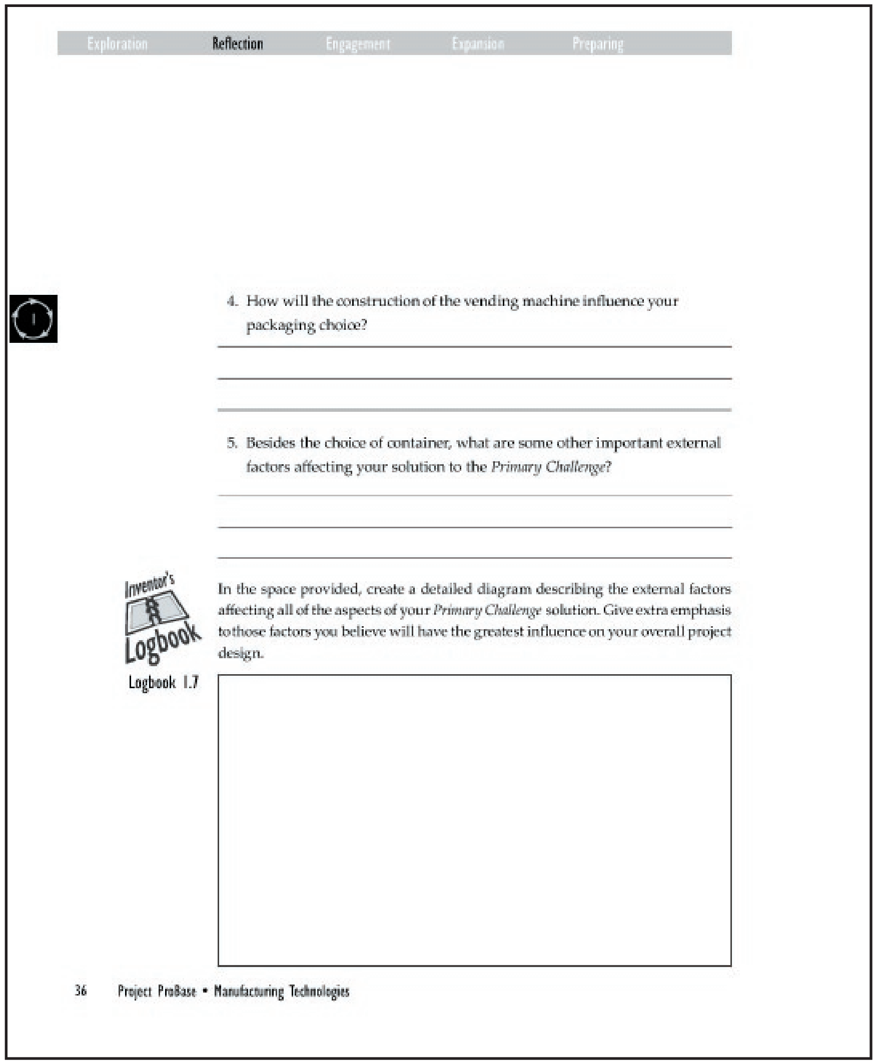
4. How will the construction of the vending machine influence your packaging choice?

5. Besides the choice of container, what are some other important external factors affecting your solution to the *Primary Challenge?*

- Make sure students record their answers in their Inventor's Logbook.

- Generate a class discussion allowing the students an opportunity to share their responses.

Students need to compile their answers into a diagram detailing all of the factors affecting their *Primary Challenge* solution. They should, in some way, indicate those factors they feel are most important to consider.


Exploration Reflection Engagement Expansion Preparing

4. How will the construction of the vending machine influence your packaging choice?

5. Besides the choice of container, what are some other important external factors affecting your solution to the *Primary Challenge*?

Inventor's Logbook

Logbook 1.7

In the space provided, create a detailed diagram describing the external factors affecting all of the aspects of your *Primary Challenge* solution. Give extra emphasis to those factors you believe will have the greatest influence on your overall project design.

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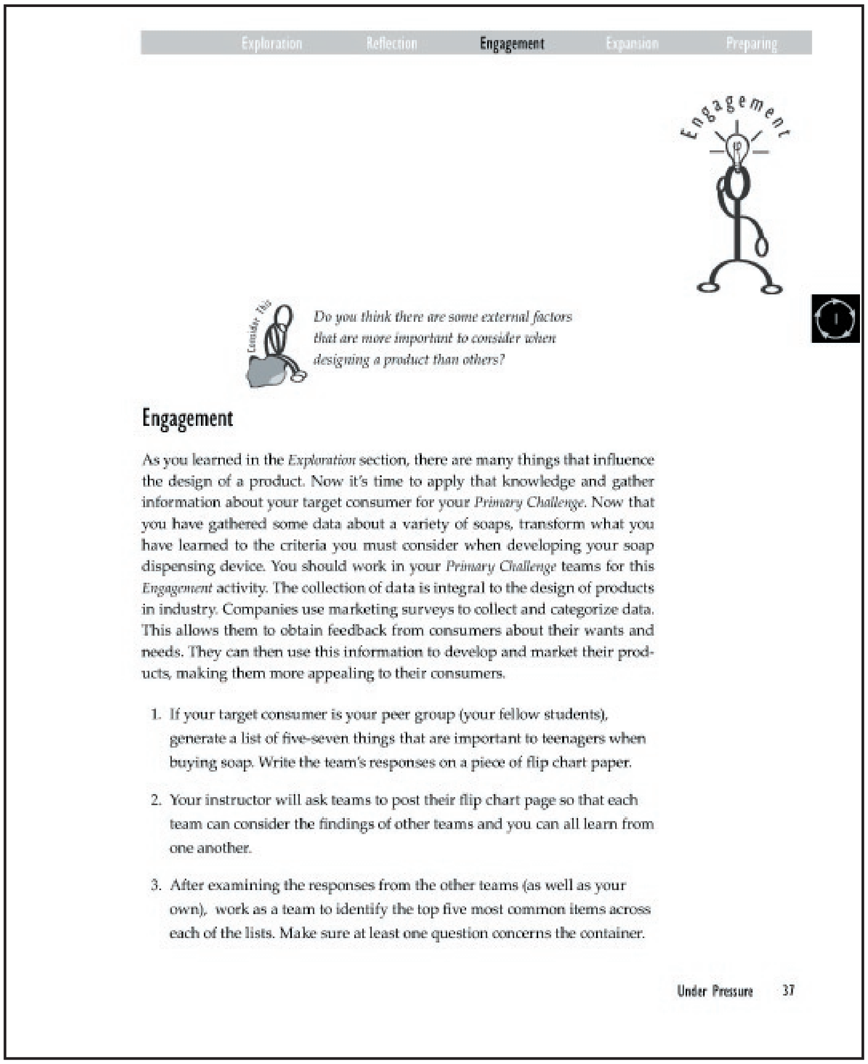
Notes:



Exploration Reflection Engagement Expansion Preparing

Engagement

Consider This

Do you think there are some external factors that are more important to consider when designing a product than others?

Engagement

As you learned in the *Exploration* section, there are many things that influence the design of a product. Now it's time to apply that knowledge and gather information about your target consumer for your *Primary Challenge*. Now that you have gathered some data about a variety of soaps, transform what you have learned to the criteria you must consider when developing your soap dispensing device. You should work in your *Primary Challenge* teams for this *Engagement* activity. The collection of data is integral to the design of products in industry. Companies use marketing surveys to collect and categorize data. This allows them to obtain feedback from consumers about their wants and needs. They can then use this information to develop and market their products, making them more appealing to their consumers.

1. If your target consumer is your peer group (your fellow students), generate a list of five-seven things that are important to teenagers when buying soap. Write the team's responses on a piece of flip chart paper.
2. Your instructor will ask teams to post their flip chart page so that each team can consider the findings of other teams and you can all learn from one another.
3. After examining the responses from the other teams (as well as your own), work as a team to identify the top five most common items across each of the lists. Make sure at least one question concerns the container.

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Engagement

- The collection of data is integral to the design of products in industry. Companies use surveys to collect and categorize data. This allows them to obtain feedback from consumers about their wants and needs. They can then use this data to develop and market their products, making them more appealing to their customers.
- It's important that each team share its responses, so ask teams to post their flip chart paper and share their ideas with the entire class.
- As a class, conduct a discussion about the common items that are listed on all of the posted papers and identify the top five most common items.

Using this list of five items, each team should create questions and a short questionnaire that could be used to assess the desires of potential customers. Students should be encouraged to refrain from open-ended responses.

For example, if fragrance is listed as a factor, a question asking, "what is your favorite fragrance?" is appropriate. Students should force respondents to choose from a few scents. A sample questionnaire item may say something like, "circle your favorite scent from the list below." This will make it much easier to analyze the data. (A sample product questionnaire is included in the Appendix, page AF, for students' reference.)

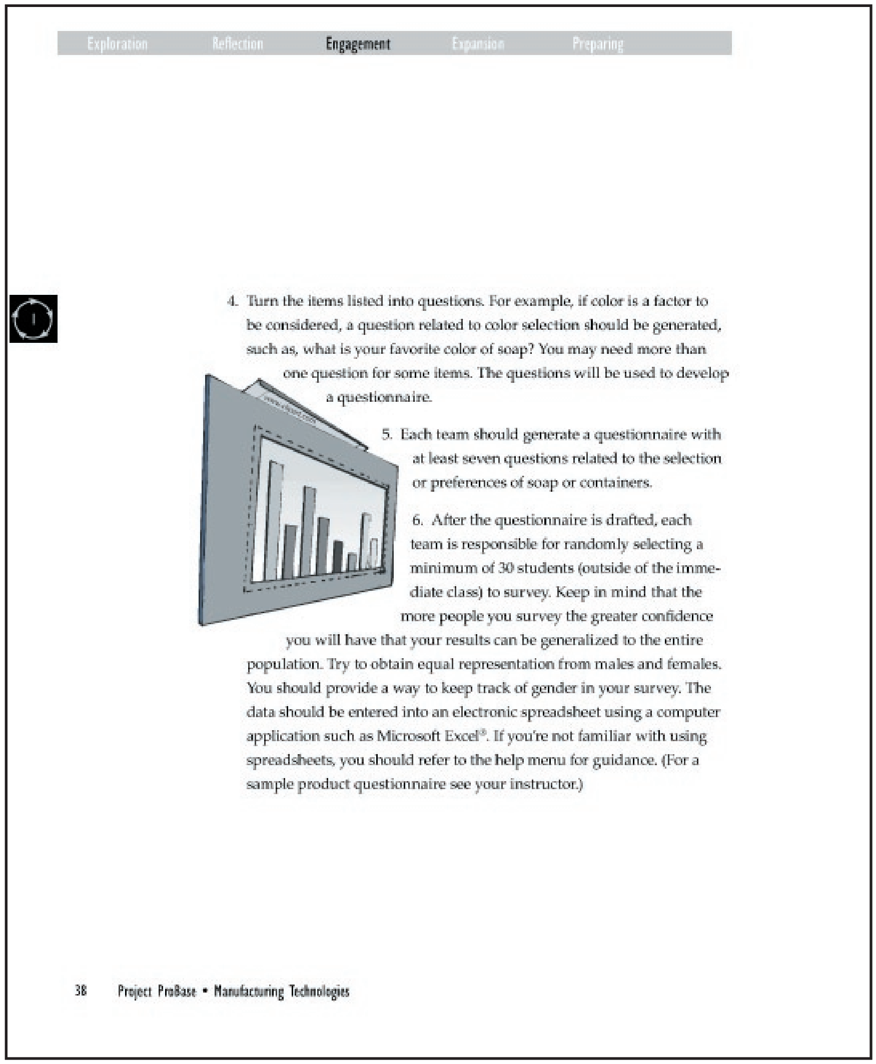
Teaching Tips

This activity should be conducted with the entire class. Students should be in their *Primary Challenge* teams. Each group should generate a list of 5-7 things that are important to teenagers when buying soap and write their responses on a piece of flip chart paper. If your students are having trouble getting started, ask them questions to lead to things that go beyond what has be discussed in the *Exploration* phase such as the cost of the product, availability, quality, style, etc.

Each team member is expected to administer the survey instrument to at least 10 students outside the immediate class. This should be assigned as homework. Remind students to survey an equal number of males and females.

- The information from the questionnaire should be compiled to identify the most preferred factors such as scent, texture.and color. Students are asked to enter the data into an electronic spreadsheet application such as Microsoft Excel®. Some students may need additional help with the use of a spreadsheet. The minimum expectations for each group should be to identify the sample size, the number of persons surveyed, the statistical mode for each response for each question and identify how their responses are distributed by gender. An example is given in the text and a statistical breakdown for one question is given in the sample questionnaire in the Appendix.

- While the data from the questionnaires are being compiled, students should be thinking about the external factors that may affect the design phase of the project.



Exploration Reflection Engagement Expansion Preparing

4. Turn the items listed into questions. For example, if color is a factor to be considered, a question related to color selection should be generated, such as, what is your favorite color of soap? You may need more than one question for some items. The questions will be used to develop a questionnaire.

5. Each team should generate a questionnaire with at least seven questions related to the selection or preferences of soap or containers.

6. After the questionnaire is drafted, each team is responsible for randomly selecting a minimum of 30 students (outside of the immediate class) to survey. Keep in mind that the more people you survey the greater confidence you will have that your results can be generalized to the entire population. Try to obtain equal representation from males and females. You should provide a way to keep track of gender in your survey. The data should be entered into an electronic spreadsheet using a computer application such as Microsoft Excel®. If you're not familiar with using spreadsheets, you should refer to the help menu for guidance. (For a sample product questionnaire see your instructor.)

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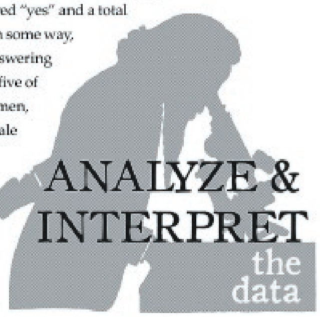
Teaching Tips

Students will need to collect all of the data that they have compiled for their solution to the *Primary Challenge*: the design of the soap container (*Reflection*), the external factors diagram (*Reflection*), and the questionnaire analysis. Remind students that they will need this information during the presentation of their team's *Primary Challenge* solution.

7. Each team must analyze the data to determine the most important factors to consider as it designs its soap dispensing device for the *Primary Challenge*. At a minimum, each group should identify the sample size, the number of persons surveyed, the statistical mode for each response for each question, and determine how these responses are distributed by gender. In order to determine the percentage for each response, you will need to divide the number of people who answered a question a certain way by the total number of people who answered that question. For example, if seven people answered "yes" and a total of nine answered the question in some way, then the percentage for those answering "yes" is rounded to 78%. And if five of those answering "yes" were women, then 55% of the total number (male and female) answering that question "yes" were women.



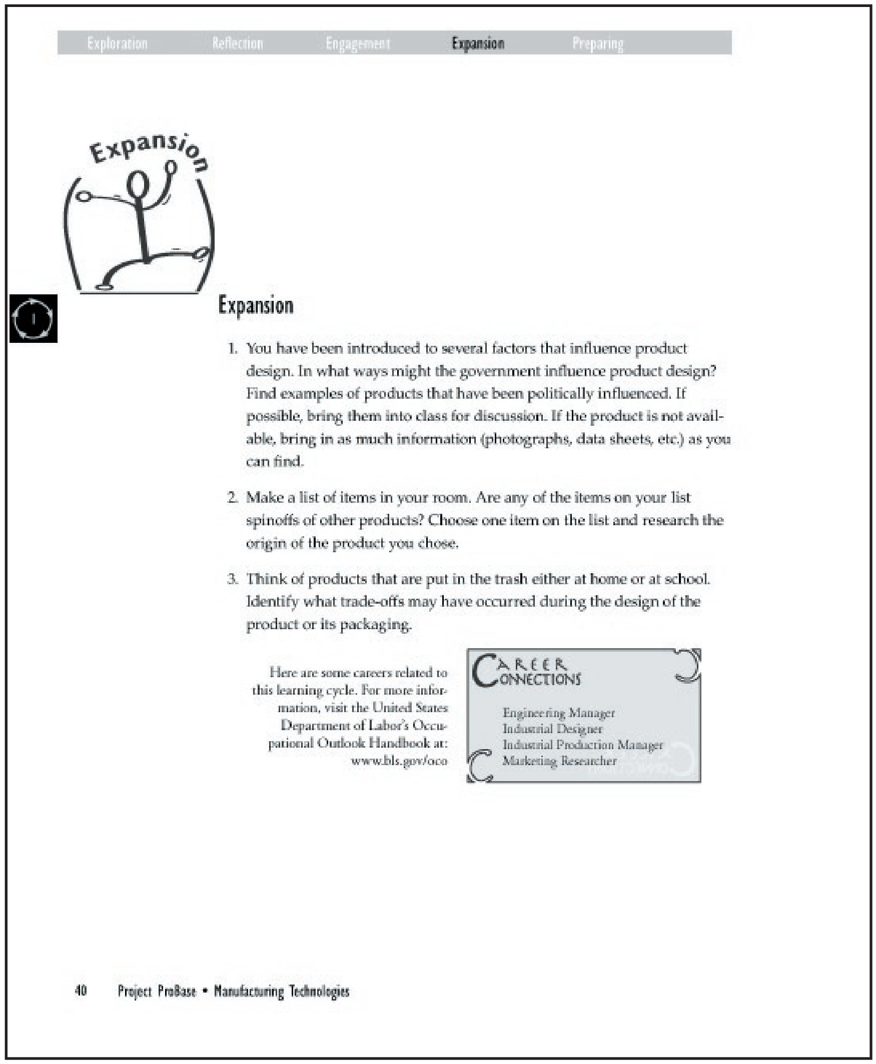
8. Collect all of your data on the design of the soap container, the external factors diagram you created during the *Reflection*, and the questionnaire analysis. Save this information in order to use it during the presentation of your team's solution to the *Primary Challenge*.

Notes:

Expansion

Although not required, these *Expansion* activities are designed to cause teams to delve deeper into the concepts explored in this learning cycle.

Students should select only one of the following *Expansion* options.


Exploration Reflection Engagement **Expansion** Preparing

Expansion

Expansion

1. You have been introduced to several factors that influence product design. In what ways might the government influence product design? Find examples of products that have been politically influenced. If possible, bring them into class for discussion. If the product is not available, bring in as much information (photographs, data sheets, etc.) as you can find.
2. Make a list of items in your room. Are any of the items on your list spinoffs of other products? Choose one item on the list and research the origin of the product you chose.
3. Think of products that are put in the trash either at home or at school. Identify what trade-offs may have occurred during the design of the product or its packaging.

Here are some careers related to this learning cycle. For more information, visit the United States Department of Labor's Occupational Outlook Handbook at: www.bls.gov/oco

CAREER CONNECTIONS

Engineering Manager
Industrial Designer
Industrial Production Manager
Marketing Researcher

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1. Students are asked to identify examples of product designs that are politically influenced. For example, looking at the side of a can of soda will reveal a list of nutrition facts. Almost everyone knows that soft drinks are not healthy, so why would the manufacturer place this information on the can, advertising the fact that their product is not really very healthy? Ask the students: "Was the decision to place this information on the product politically motivated?" Students should be encouraged to generate ideas or research products that are influenced by state or federal policies.
2. Students should be able to generate a list of items from their room. Encourage the students to closely examine what they see in their room. There are probably many things that they would not expect to be a spinoff that in fact are. Students should not exclude items they are unsure about. After students have compiled a list and have identified which are spinoffs, allow each group to do an Internet search on "spinoffs" and "inventions" to verify whether they are correct.
3. Students are asked to think of products that are put in the trash either at home or at school. From the products they identify, they should be able to list possible trade-offs that influenced the design of the product. For example, if the package looks very flashy, it may not be environmentally friendly. Encourage students to look closely at how the product or package was designed.

Exploration Reflection Engagement Expansion **Preparing**

As you think about what influences the development of your soap dispensing device, keep in mind that the consumer needs must be met. The more in tune you are with what your consumer wants the more competitive your product will be. In preparing for the *Primary Challenge*, your team must decide what preferences will be available within the device. In your *Primary Challenge* team, create a Consumer Preference table that outlines the type of soap you are going to choose, the fragrance choices and color choices that will be available to the consumer, and possible sources for purchasing each ingredient. Provide this table to your instructor, complete with supplier's contact information so that materials needed for your solution can be ordered.

Logbook 1.8

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Student Assessment

An assessment rubric has been developed for the *Exploration* and *Engagement* activities. Feel free to change this rubric to better suit your particular needs.

Preparing for the Challenge

Have the students look at the information that was collected from the survey questionnaires to inform their decision about the characteristics that their liquid soap will have during the solution of the *Primary Challenge*.

Students should generate a materials list and research possible vendors on the Internet. This list should be used to order supplies for the *Primary Challenge.*

Under Pressure

Element	Criteria				Points
	4	3	2	1	
Spinoffs	Questions were answered in Inventor's Logbook spaces. Created a complete flow chart illustrating the group's idea concerning the Business Lunchable®.	Incomplete answers in Inventor's Logbook spaces. Created a complete flow chart illustrating the group's idea concerning the Business Lunchable®.	Incomplete answers in Inventor's Logbook spaces. Created an incomplete flow chart illustrating the group's idea concerning the Business Lunchable®.	Did not answer questions in Inventor's Logbook spaces. Created an incomplete flow chart illustrating the group's idea concerning the Business Lunchable®.	
Customer Data	Complete charts and personal list of things important to consider when purchasing soap recorded in Inventor's Logbook spaces.	Each chart was somewhat complete. A personal list of things important to consider when purchasing soap recorded in Inventor's Logbook spaces.	Each chart was incomplete. A personal list of things important to consider when purchasing soap recorded in Inventor's Logbook spaces.	Each chart was complete. A personal list of things important to consider when purchasing soap is not recorded in Inventor's Logbook spaces.	
Societal and Environmental Factors	Developed a chart outlining how each product was packaged and the impact society had on the product design. Fully answered the five questions. Created a detailed diagram of the external factors affecting their solution to the *Primary Challenge*.	Developed a chart outlining how each product was packaged and somewhat developed an explanation of the impact society had on the design. Somewhat answered the five questions. Did not create a very detailed diagram.	Did not develop a chart that identified how the product was packaged but did develop an explanation of the impact society had on the design. Answered most of the five questions but did not create a diagram.	Developed a chart that identified how the product was packaged but did not develop an explanation of the impact of society. Answered only a few of the five questions and did not create a diagram.	
Engagement	Generated good questions for the survey. Completed a survey questionnaire and did the statistical analysis correctly. Collected the data for the *Primary Challenge*. Group chose the preferences to be included in their device. Created table and turned it in to the instructor.	Generated good questions for the survey. Completed a survey questionnaire and did some of the statistical analysis correctly. Collected most of the data. Group was undecided about preferences to be included in their device. Began a table but did not turn it in to the instructor.	Generated good questions for the survey. Completed a survey questionnaire but did not do the statistical analysis correctly or at all. Did not collect the data. Group was undecided about preferences to be included in their device. Did not create a table.	Generated good questions for the survey. Did not complete a survey questionnaire. Did not collect the data. Group was undecided about preferences to be included in their device. Did not create a table.	
				Totals	

Learning Cycle Two

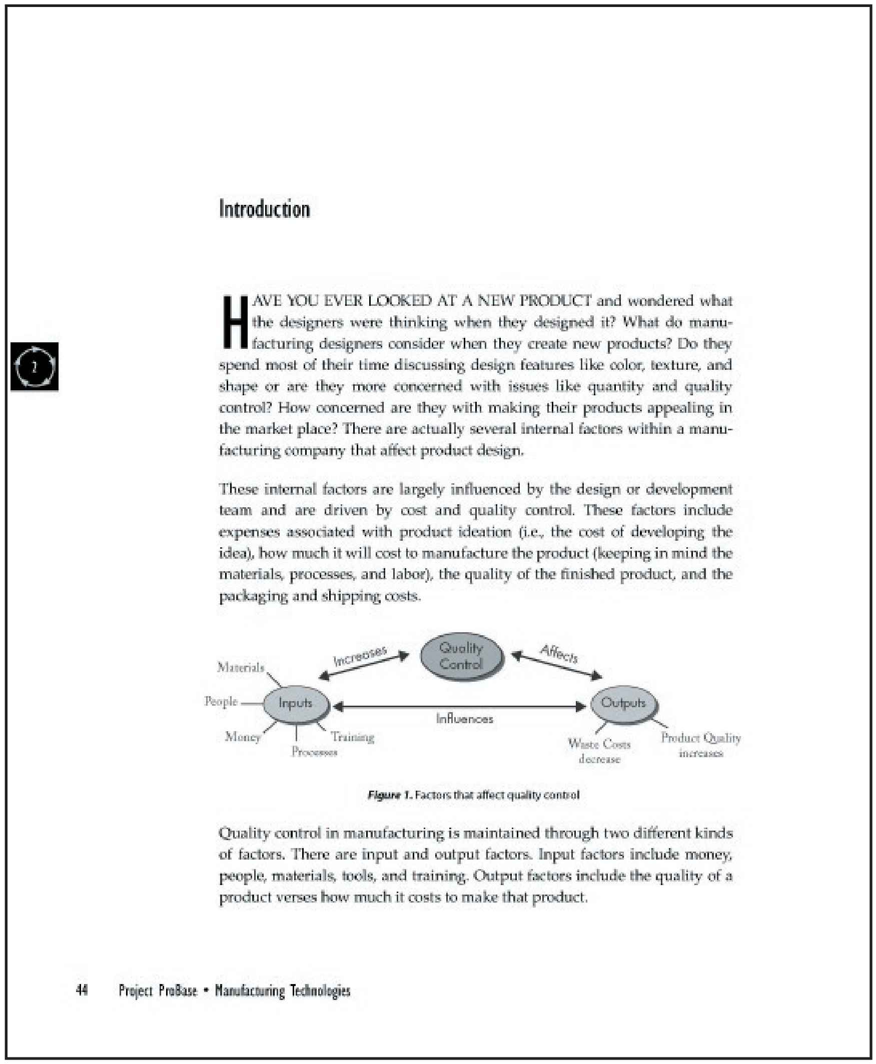
As Good As It Gets

As Good As It Gets

Introduction

In this learning cycle, students explore factors that affect the quality control in manufacturing processes. In order for students to understand how quality control is maintained in a production line, they will design a quality control system that will help them assess the quality of a collection of paper clips. This quality control system will also help them to decide whether or not each paper clip is a "go" or "no go" with respect to a set of standards.

The concept of production costs will be explored as students create a trail mix product and calculate the cost of producing various amounts of their product. During the *Engagement* phase, students will begin to think about the *Primary Challenge* by brainstorming the materials, processes, and the means to control the quality of their liquid soap dispensing device.



Introduction

HAVE YOU EVER LOOKED AT A NEW PRODUCT and wondered what the designers were thinking when they designed it? What do manufacturing designers consider when they create new products? Do they spend most of their time discussing design features like color, texture, and shape or are they more concerned with issues like quantity and quality control? How concerned are they with making their products appealing in the market place? There are actually several internal factors within a manufacturing company that affect product design.

These internal factors are largely influenced by the design or development team and are driven by cost and quality control. These factors include expenses associated with product ideation (i.e., the cost of developing the idea), how much it will cost to manufacture the product (keeping in mind the materials, processes, and labor), the quality of the finished product, and the packaging and shipping costs.

Figure 1. Factors that affect quality control

Quality control in manufacturing is maintained through two different kinds of factors. There are input and output factors. Input factors include money, people, materials, tools, and training. Output factors include the quality of a product verses how much it costs to make that product.

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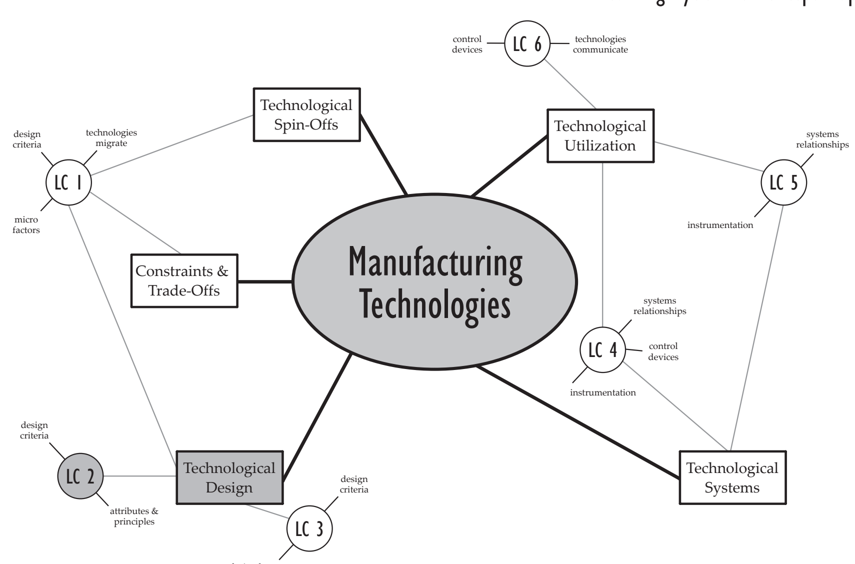
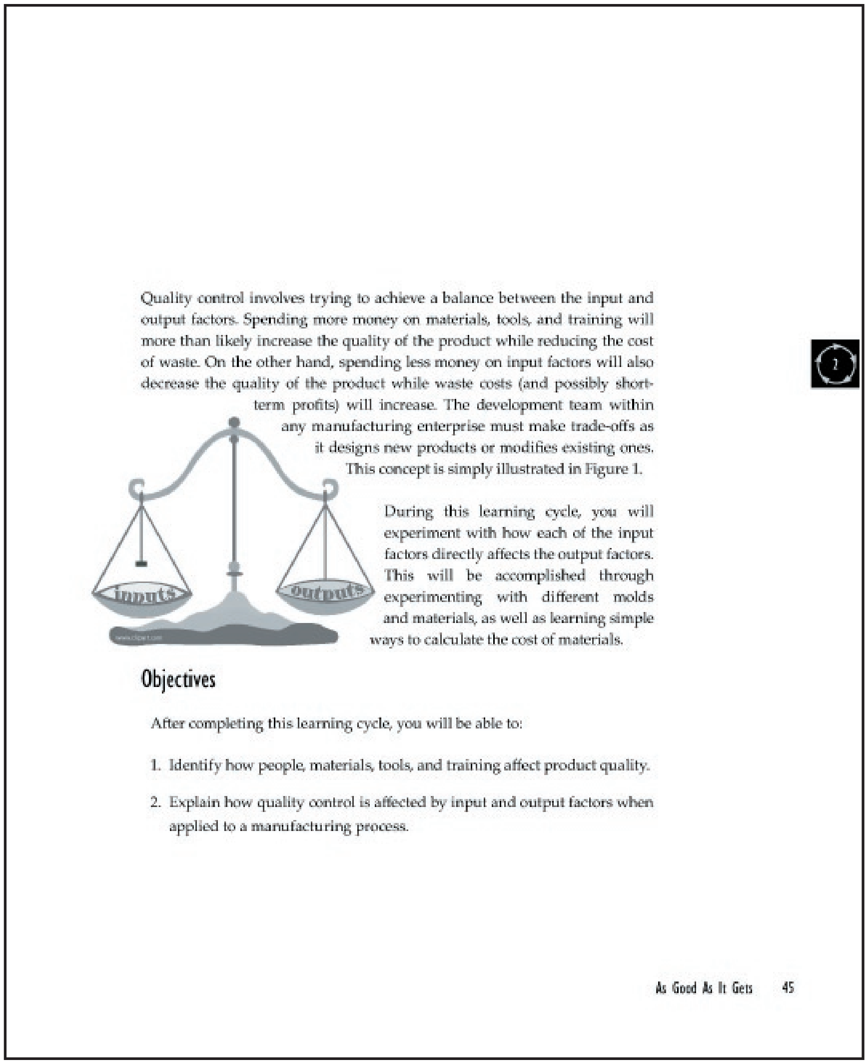
Manufacturing Technologies
Learning Cycle Two Concept Map





Quality control involves trying to achieve a balance between the input and output factors. Spending more money on materials, tools, and training will more than likely increase the quality of the product while reducing the cost of waste. On the other hand, spending less money on input factors will also decrease the quality of the product while waste costs (and possibly short-term profits) will increase. The development team within any manufacturing enterprise must make trade-offs as it designs new products or modifies existing ones. This concept is simply illustrated in Figure 1.

During this learning cycle, you will experiment with how each of the input factors directly affects the output factors. This will be accomplished through experimenting with different molds and materials, as well as learning simple ways to calculate the cost of materials.

Objectives

After completing this learning cycle, you will be able to:

1. Identify how people, materials, tools, and training affect product quality.
2. Explain how quality control is affected by input and output factors when applied to a manufacturing process.

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Objectives and Essential Questions

After completing this learning cycle, students will be able to:

1. Identify how people, materials, tools, and training affect product quality.

Essential Question 7c: What design criteria is typically considered when developing new technologies (e.g., marketability, safety, usability, reliability, cost, materials) and how do these factors influence the final product/system design?

2. Explain how quality control is affected by input and output factors when applied to a manufacturing process.

Essential Question 7e: How can the attributes of design and the principles of design aid in the development of quality

Facility Requirements

Classroom area with large open bench tops for stations to be set up and clean areas where food handling can take place are necessary for this learning cycle.

Equipment and Materials

Small measuring cup set (1 C, ½ C, ¼ C)

5-10 big plastic bowls

A bag of paper clips

Soap

(28) Disposable plastic gloves

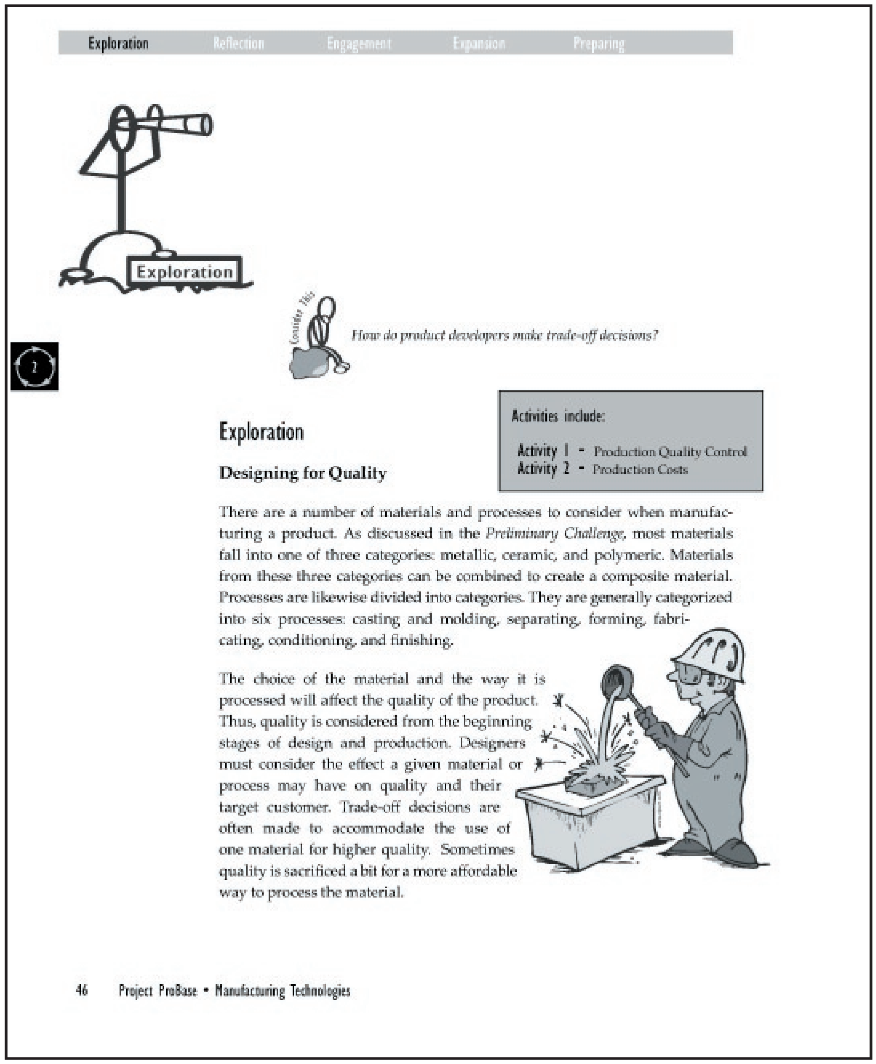
1 bag per team of:
- Raisins
- Peanuts
- M&M's
- Sunflower seeds
- Ziploc bags
- Paper bowls

(7) Timers

Estimated number of 50-minute class periods: **5**

Suggested Daily Outline

Day One	Day Two
Exploration Production Quality Control	*Exploration* Product Costs
Day Three	**Day Four**
Reflection	*Engagement*
Day Five	
Engagement *Preparing for the Challenge*	


Exploration Reflection Engagement Expansion Preparing

Exploration

How do product developers make trade-off decisions?

Activities include:
Activity 1 - Production Quality Control
Activity 2 - Production Costs

Exploration

Designing for Quality

There are a number of materials and processes to consider when manufacturing a product. As discussed in the *Preliminary Challenge*, most materials fall into one of three categories: metallic, ceramic, and polymeric. Materials from these three categories can be combined to create a composite material. Processes are likewise divided into categories. They are generally categorized into six processes: casting and molding, separating, forming, fabricating, conditioning, and finishing.

The choice of the material and the way it is processed will affect the quality of the product. Thus, quality is considered from the beginning stages of design and production. Designers must consider the effect a given material or process may have on quality and their target customer. Trade-off decisions are often made to accommodate the use of one material for higher quality. Sometimes quality is sacrificed a bit for a more affordable way to process the material.

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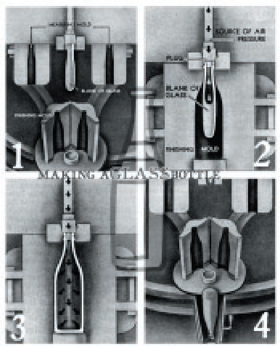
Exploration

Teaching Tips

During this learning cycle, students will complete two different but related tasks. The most efficient way to approach this may be to set up a station for each activity and have your students rotate as they complete each task. Depending on the number of teams, you may decide to duplicate one or more of the stations in order to accommodate a larger number of students.

The choice of material used for a tennis racket frame, for example, greatly impacts its quality. The traditional tennis racket was made from a wooden frame. However, because of design limitations (smaller heads required to accommodate the strings) new materials, like graphite and titanium, are now used to make frames. Trade-offs in the design process are made to accommodate quality and cost with the consumer in mind. The "better" the material, the higher the quality and often the higher the price. Aluminum tennis rackets are inexpensive, but in terms of performance they are lower in quality. Carbon, graphite, and titanium composite tennis rackets are more expensive, but allow for higher quality performance for consumers.



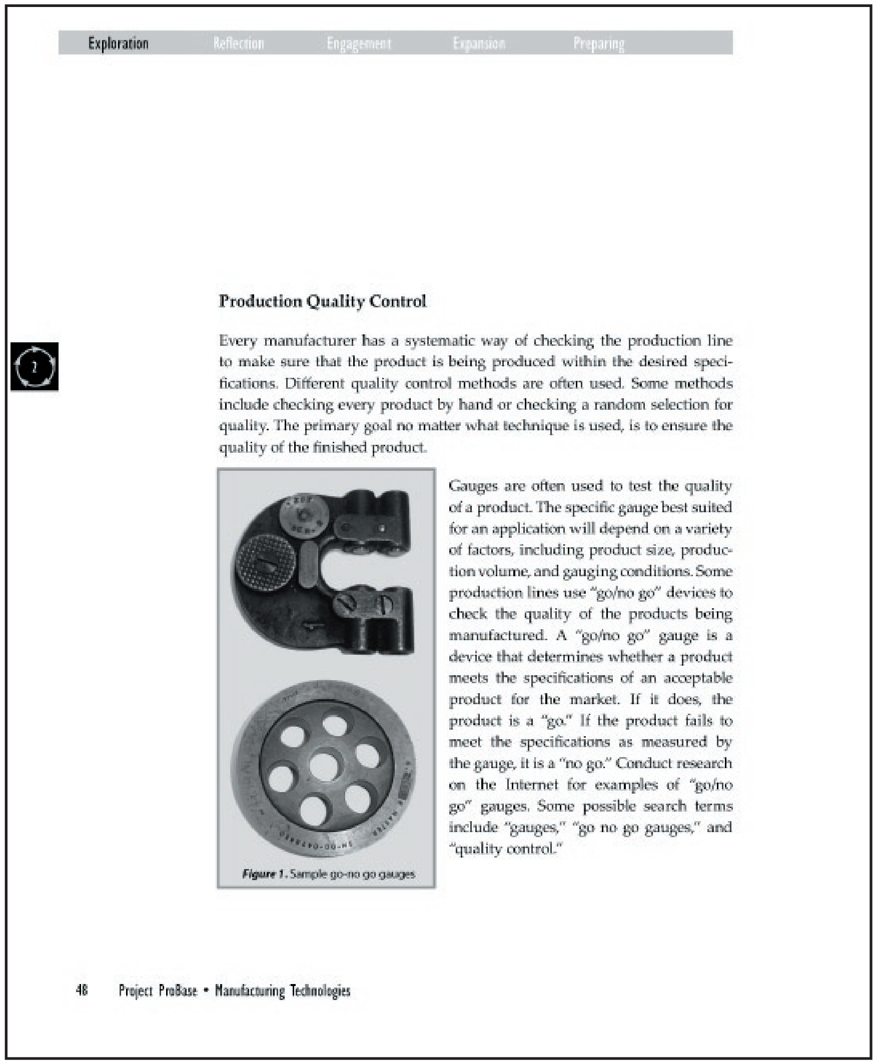
Notes:

Production Quality Control

Provide a variety of materials for the students to use such as wood, cardboard, and paper. Encourage your students to be creative.

You will need to purchase several bags of paper clips. Choose one of the paper clips as the "master" or desired size that the students will be using as a standard. You will need to go through the paper clips (prior to supplying the students with several) to know how many do not meet the standard specifications. If there is not much variability among the paper clips you can simply alter a number of the paper clips to make certain that they will measure outside the +/- 1 mm specifications outlined in the activity. (Keep track of how many you altered.)

The students will need to check the number that they said were a "go" against the number that you previously counted. This station will also need basic construction tools such as a hammer, small finishing nails, hot glue gun, ruler, and scissors.


Exploration Reflection Engagement Expansion Preparing

Production Quality Control

Every manufacturer has a systematic way of checking the production line to make sure that the product is being produced within the desired specifications. Different quality control methods are often used. Some methods include checking every product by hand or checking a random selection for quality. The primary goal no matter what technique is used, is to ensure the quality of the finished product.

Gauges are often used to test the quality of a product. The specific gauge best suited for an application will depend on a variety of factors, including product size, production volume, and gauging conditions. Some production lines use "go/no go" devices to check the quality of the products being manufactured. A "go/no go" gauge is a device that determines whether a product meets the specifications of an acceptable product for the market. If it does, the product is a "go." If the product fails to meet the specifications as measured by the gauge, it is a "no go." Conduct research on the Internet for examples of "go/no go" gauges. Some possible search terms include "gauges," "go no go gauges," and "quality control."

Figure 1. Sample go-no go gauges

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Teaching Tips

In this task, student teams create a jig to check the length of paper clips. Although you should not tell the students exactly how to solve this problem, you should provide them with samples of different types of jigs or Internet access to conduct research to find their own examples. The vacuum formed packaging used to display products in a retail shop can serve as a good illustration of a go/no-go gauge.

Students are given several Inventor's Logbook entries related to Production Control and their go/no-go gauge.

Exploration Reflection Engagement Expansion Preparing

1. Obtain the "master" paper clip and a bag of paper clips from your instructor.
2. Your team is required to create a "go/no go" quality control device.
3. Measure the length and diameter of the "master" paper clip as designated by your instructor. Create a "go/no go" gauge that will ensure that each of your paper clips is within +/-1 mm of the specifications established from the "master" paper clip. The gauge needs to be able to account for the paper clips that are 1 mm longer or wider and 1 mm shorter or thinner than the master. If the product is within the tolerance (+/- 1 mm) it may pass the accepted product quality and "go" on. If it fails, it is a "no go" and must be rejected.
4. Use the gauge that your team created to test each of the paper clips. Separate the clips that pass the quality test from those that are not within the required specifications. Count how many clips were a "go" and how many were a "no go." Create a table in the Inventor's Logbook space provided that identifies the types of flaws found in rejected clips as well as the raw number of good and rejected clips.

Inventor's Logbook

Logbook 2.1

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Exploration Reflection Engagement Expansion Preparing

Inventor's Logbook

Logbook 2.2

1. What percentage of the clips were able to "go"?

2. Let's assume that each team in your class had a "master" paper clip with the exact same dimensions. Compile the data as a class and calculate the percentage of paper clips that fell outside the tolerance and provide your answer in the Inventor's Logbook space below.

As a class, discuss plausible reasons for the variations found in the paper clips. Why do variations occur in production? How important is quality for this type of product versus a product such as a heart monitor or computer? How critical is it to sales that manufacturers meet certain criteria such as size, appearance, and quantity?

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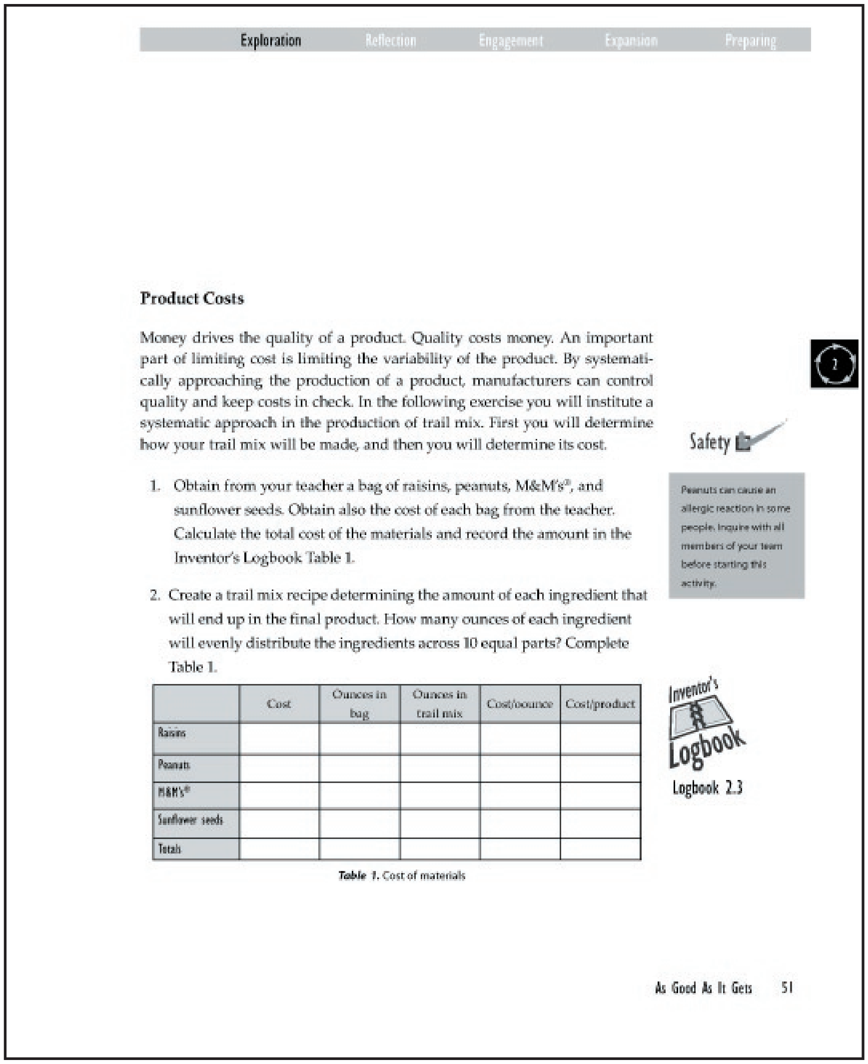
Notes:

Product Costs



Exploration Reflection Engagement Expansion Preparing

Product Costs

Money drives the quality of a product. Quality costs money. An important part of limiting cost is limiting the variability of the product. By systematically approaching the production of a product, manufacturers can control quality and keep costs in check. In the following exercise you will institute a systematic approach in the production of trail mix. First you will determine how your trail mix will be made, and then you will determine its cost.

Safety

Peanuts can cause an allergic reaction in some people. Inquire with all members of your team before starting this activity.

1. Obtain from your teacher a bag of raisins, peanuts, M&M's®, and sunflower seeds. Obtain also the cost of each bag from the teacher. Calculate the total cost of the materials and record the amount in the Inventor's Logbook Table 1.

2. Create a trail mix recipe determining the amount of each ingredient that will end up in the final product. How many ounces of each ingredient will evenly distribute the ingredients across 10 equal parts? Complete Table 1.

	Cost	Ounces in bag	Ounces in trail mix	Cost/ounce	Cost/product
Raisins					
Peanuts					
M&M's®					
Sunflower seeds					
Totals					

Table 1. Cost of materials

Inventor's Logbook

Logbook 2.3

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Teaching Tips

Students are learning how money drives the quality of a product in this task by making trail mix. Since the students will be handling food, it is important that each student wear disposable plastic gloves. The area for this task should be clean and the counter top covered with plastic. It is also important that you are aware of student food allergies; some students may be allergic to peanuts. You can substitute another food like marshmallows for the peanuts.

To the right of each of the food items is an example of what the students should do. The data in the table are supplied as a sample and do not represent actual answers. Data will differ depending on the size of bag that you purchase.

	Cost	Ounces in bag	Ounces in trail mix	Cost/ounce	Cost per product
Raisins	2.99	24	2.4	0.12	0.30
Peanuts	2.65	24	2.4	0.11	0.27
M & M's	3.99	16	1.6	0.25	0.40
Sunflower seeds	2.99	16	1.6	0.18	0.30
Totals	12.62		8.0	0.66	1.27

Figure 2. Cost of materials table

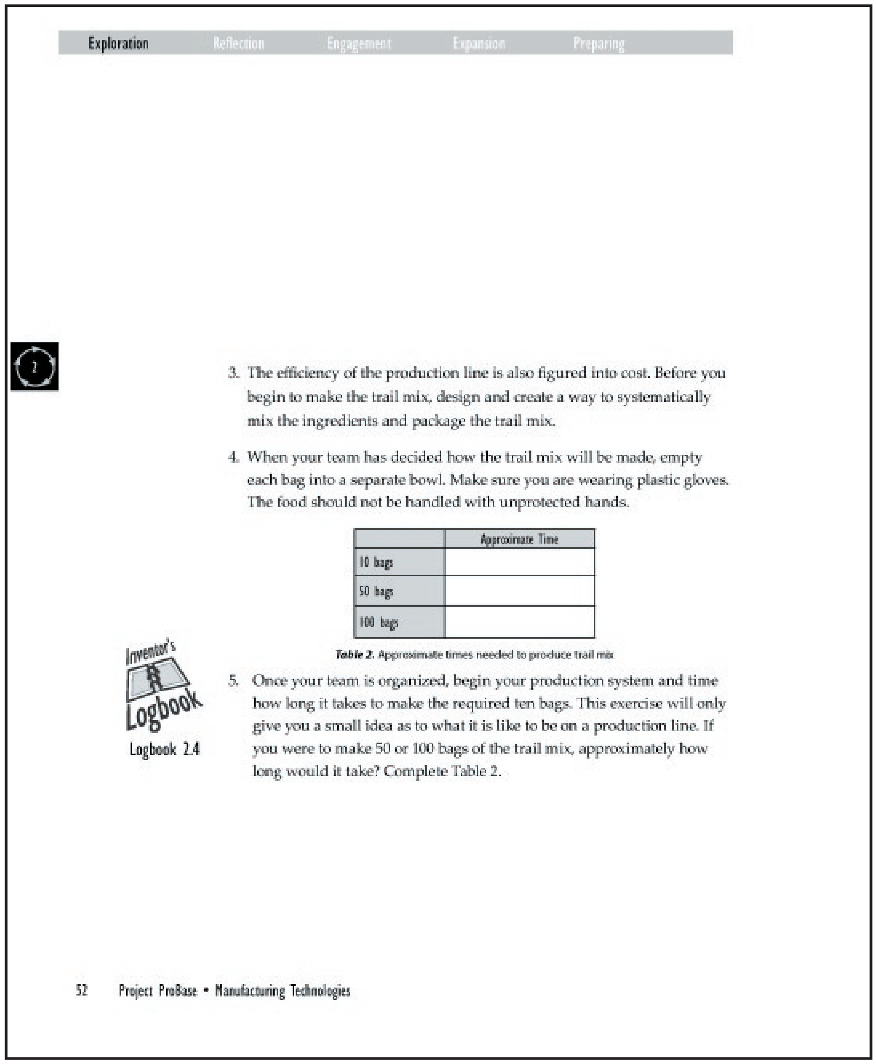
After students have devised a way to mix the trail mix they should produce 10 bags of mix and record the amount of time required to complete the task. Students are then asked to use the data for 10 bags and calculate how long it would take to produce 50 and 100 bags of trail mix. When students are asked to complete Figure 3, their answers will vary depending on how efficiently they put all the ingredients together in the trail mix.

	Approximate Time
10 bags	9
50 bags	45
100 bags	90

Figure 3. Approximate times needed to produce trail mix

Next, students are asked to consider the costs associated with producing the different amounts of trail mix when labor costs and production times are factored into the final cost.

If each person is paid $6.50 an hour, how much would the labor cost for making 50 bags of trail mix the way the team designed their production line?



Exploration Reflection Engagement Expansion Preparing

3. The efficiency of the production line is also figured into cost. Before you begin to make the trail mix, design and create a way to systematically mix the ingredients and package the trail mix.

4. When your team has decided how the trail mix will be made, empty each bag into a separate bowl. Make sure you are wearing plastic gloves. The food should not be handled with unprotected hands.

	Approximate Time
10 bags	
50 bags	
100 bags	

Table 2. Approximate times needed to produce trail mix

Inventor's Logbook

Logbook 2.4

5. Once your team is organized, begin your production system and time how long it takes to make the required ten bags. This exercise will only give you a small idea as to what it is like to be on a production line. If you were to make 50 or 100 bags of the trail mix, approximately how long would it take? Complete Table 2.

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If there are 4 people on the team, and the team took one hour to produce 50 bags of trail mix, the labor cost would equal $26.00 (4 x $6.50= $26.50).

However, using the times presented in the example in Figure 3, it took 45 minutes to produce 50 bags of trail mix.

Therefore, the labor would cost $19.50 (4 x $6.50 x .75=$19.50).

One hundred bags would cost $39.00 (4 x 6.50 x 1.5 = $39.00).

Exploration Reflection Engagement Expansion Preparing

6. From the information you acquired in the previous steps, create a chart in the Inventor's Logbook space provided that shows how much it costs per bag of trail mix when time and labor are considered. In this exercise, the cost for labor is $6.50 an hour per person. Your table should indicate how much it would cost to make 50 and 100 bags of trail mix in your team's production line.

Employee Labor Expense Table	30 min	1hr	8hr
Employee #1 $________			
Employee #2 $________			
Employee #3 $________			
Employee #4 $________			
Total Labor Cost/Time Period			

Inventor's Logbook

Logbook 2.5

As a team, discuss the quality of your finished trail mix. Is there anything that you could change in your production system to improve the quality of this product? List the quality indicators that your team used to judge the quality of the finished product in the Inventor's Logbook space provided.

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Teaching Tips

The Student Guide has the labor cost fixed at $6.00/hr. You may want to adjust the labor cost for each employee to make the task more realistic to the industry and add a level of difficulty for your students.

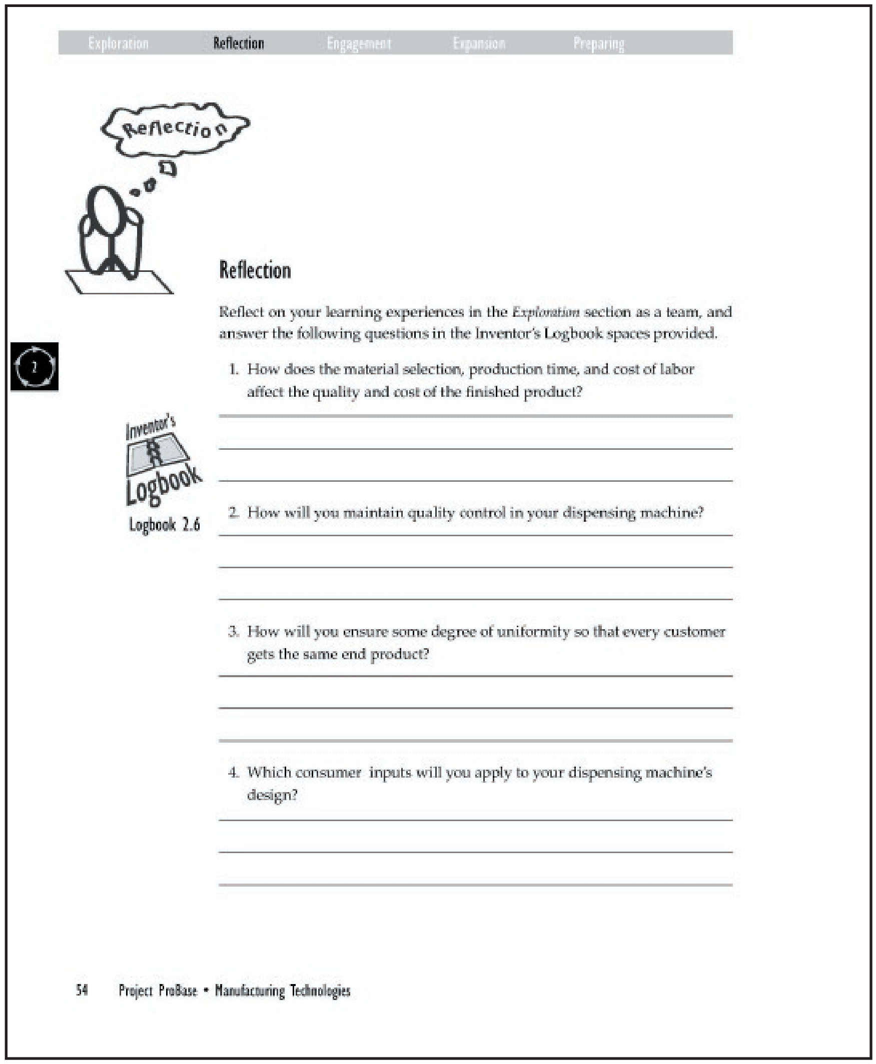
Employee Labor Expense Table	30 min	1hr	8hr
Employee #1 $________			
Employee #2 $________			
Employee #3 $________			
Employee #4 $________			
Total Labor Cost/Time Period			

Reflection

Students in this section are asked to reflect on their learning experiences in the *Exploration* phase and answer the following questions in the Inventor's Logbook spaces provided in their text.

1. How does the materials selection, production time, and cost of labor affect the quality and cost of the finished product?

2. How will you maintain quality control in your dispensing machine?



Exploration Reflection Engagement Expansion Preparing

Reflection

Inventor's Logbook

Logbook 2.6

Reflection

Reflect on your learning experiences in the *Exploration* section as a team, and answer the following questions in the Inventor's Logbook spaces provided.

1. How does the material selection, production time, and cost of labor affect the quality and cost of the finished product?
2. How will you maintain quality control in your dispensing machine?
3. How will you ensure some degree of uniformity so that every customer gets the same end product?
4. Which consumer inputs will you apply to your dispensing machine's design?

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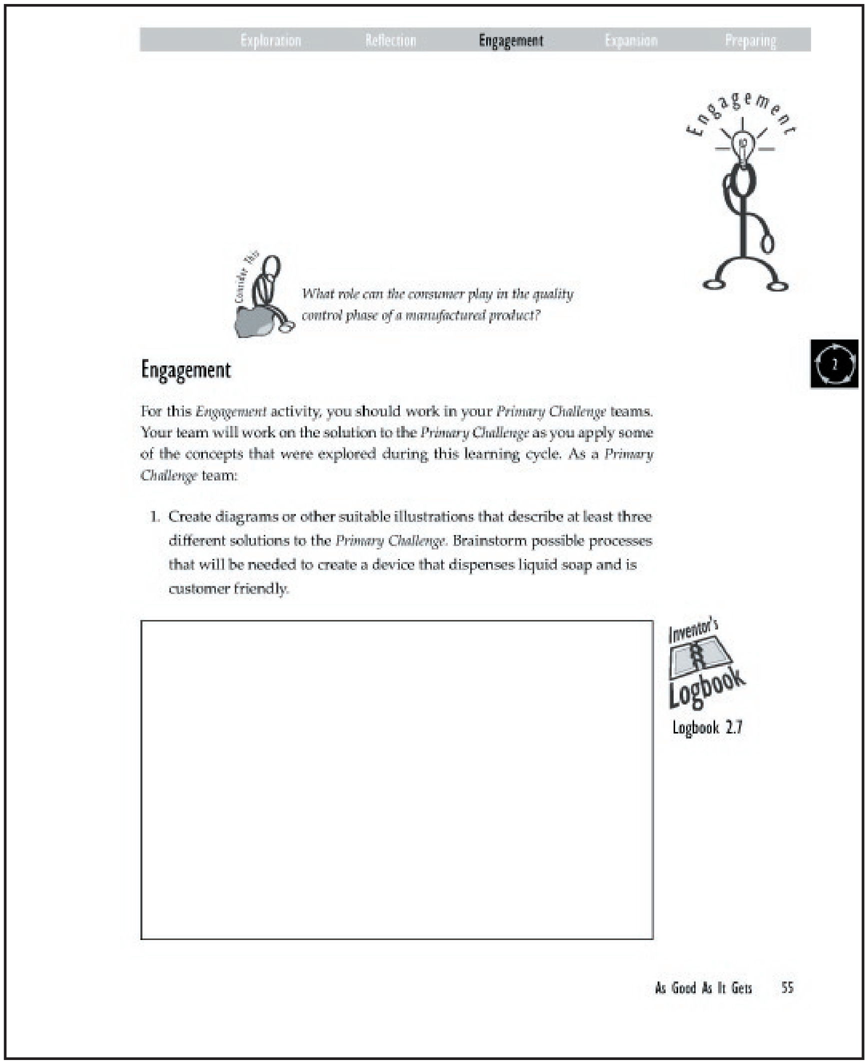
3. How will you ensure some degree of uniformity so that every customer gets the same end product?

4. Which consumer inputs will you apply to your dispensing machine's design?



Exploration Reflection Engagement Expansion Preparing

Engagement

Consider this

What role can the consumer play in the quality control phase of a manufactured product?

Engagement

For this *Engagement* activity, you should work in your *Primary Challenge* teams. Your team will work on the solution to the *Primary Challenge* as you apply some of the concepts that were explored during this learning cycle. As a *Primary Challenge* team:

1. Create diagrams or other suitable illustrations that describe at least three different solutions to the *Primary Challenge*. Brainstorm possible processes that will be needed to create a device that dispenses liquid soap and is customer friendly.

Inventor's Logbook

Logbook 2.7

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Engagement

Students are expected to brainstorm possible materials that they will use for the proposed process. Let the students see materials that will be available to them before they begin to lay out the process that they intend to employ to create their soap dispensing device. If they need a material that you do not have available, require them to provide a written rationale for using that material and have them provide possible vendors.

As part of this *Engagement* activity, students are required to identify the internal factors that will affect their team's solution to the *Primary Challenge*. These factors include expenses associated with the cost of developing the idea, how much it will cost to produce the product (keeping in mind the materials, processes, and labor), the quality of the finished product, and the packaging and shipping costs. Students are provided space in their text to record these factors. Encourage them to save their list and share it with the class during the presentation of their solution.

Teaching Tips

Students are expected to diagram or illustrate at least three different solutions to the *Primary Challenge*. Provide them with time to get into their *Primary Challenge* teams to brainstorm ideas and work on their diagrams.

This learning cycle has briefly explored the concept of quality control. Students are asked to identify specifications for quality control within their soap dispensing device. Each team should generate a list of specifications to guide their quality control.

For example, the dispensing device should dispense 1 ounce of soap to each customer, or the process of dispensing soap should take no longer than 10 seconds. To make these requirements most efficient, you may want to encourage your students to assign various team members to the actual work after the brainstorming work has been completed.

2. Brainstorm possible materials that you will use for each proposed process during the solution of the *Primary Challenge*. Your instructor will help your team by listing the materials on the board that are available for your use. If a material is not listed and your team feels that it is required for your solution, you must provide your instructor with a written rationale for using this material that includes the cost and a possible source or other options for obtaining it.

Inventor's Logbook

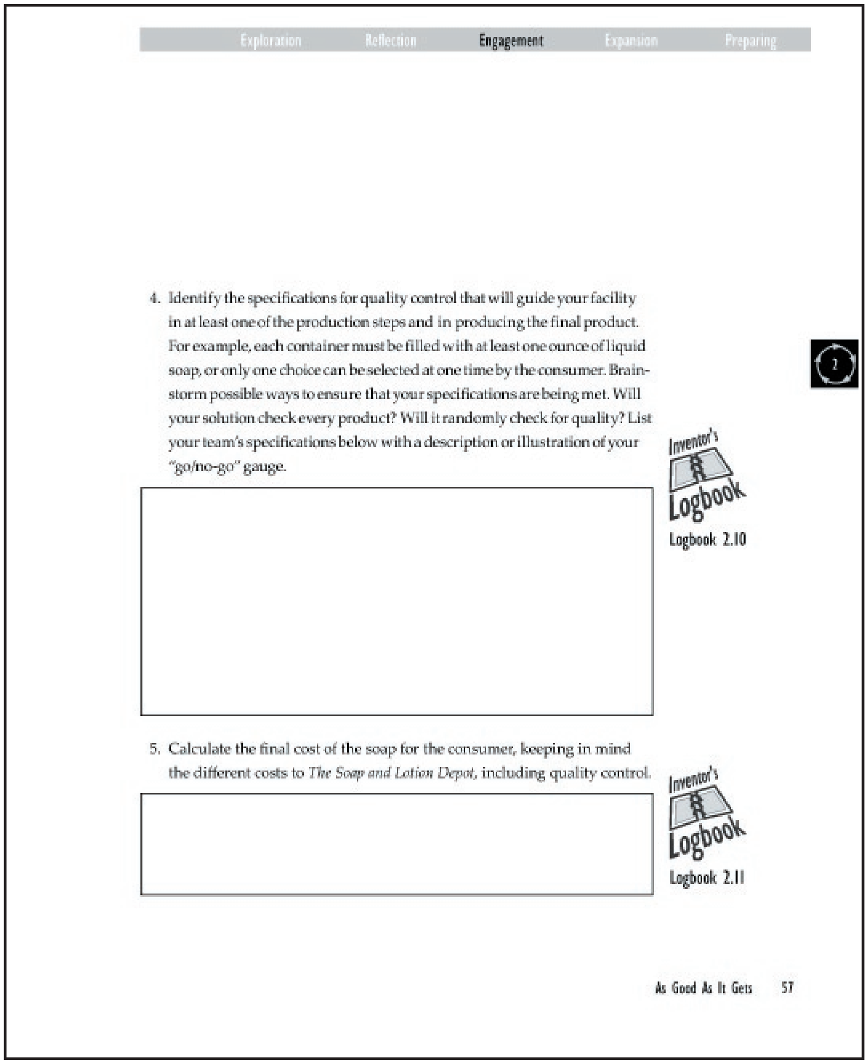
Logbook 2.8

3. Identify the internal factors that will affect your team's solution to the *Primary Challenge*. Record this information in the space below so that it can be used during the presentation of your team's solution.

Inventor's Logbook

Logbook 2.9

Finally, each team should calculate the final cost of the soap for the consumer. The students should consider the various internal factors that will contribute to determining a price. For example, the cost to produce the product (the materials, processes, and labor), the quality of the finished product and the packaging costs should all be considered.


Exploration Reflection Engagement Expansion Preparing

4. Identify the specifications for quality control that will guide your facility in at least one of the production steps and in producing the final product. For example, each container must be filled with at least one ounce of liquid soap, or only one choice can be selected at one time by the consumer. Brainstorm possible ways to ensure that your specifications are being met. Will your solution check every product? Will it randomly check for quality? List your team's specifications below with a description or illustration of your "go/no-go" gauge.

Inventor's Logbook

Logbook 2.10

5. Calculate the final cost of the soap for the consumer, keeping in mind the different costs to *The Soap and Lotion Depot*, including quality control.

Inventor's Logbook

Logbook 2.11

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Teaching Tips

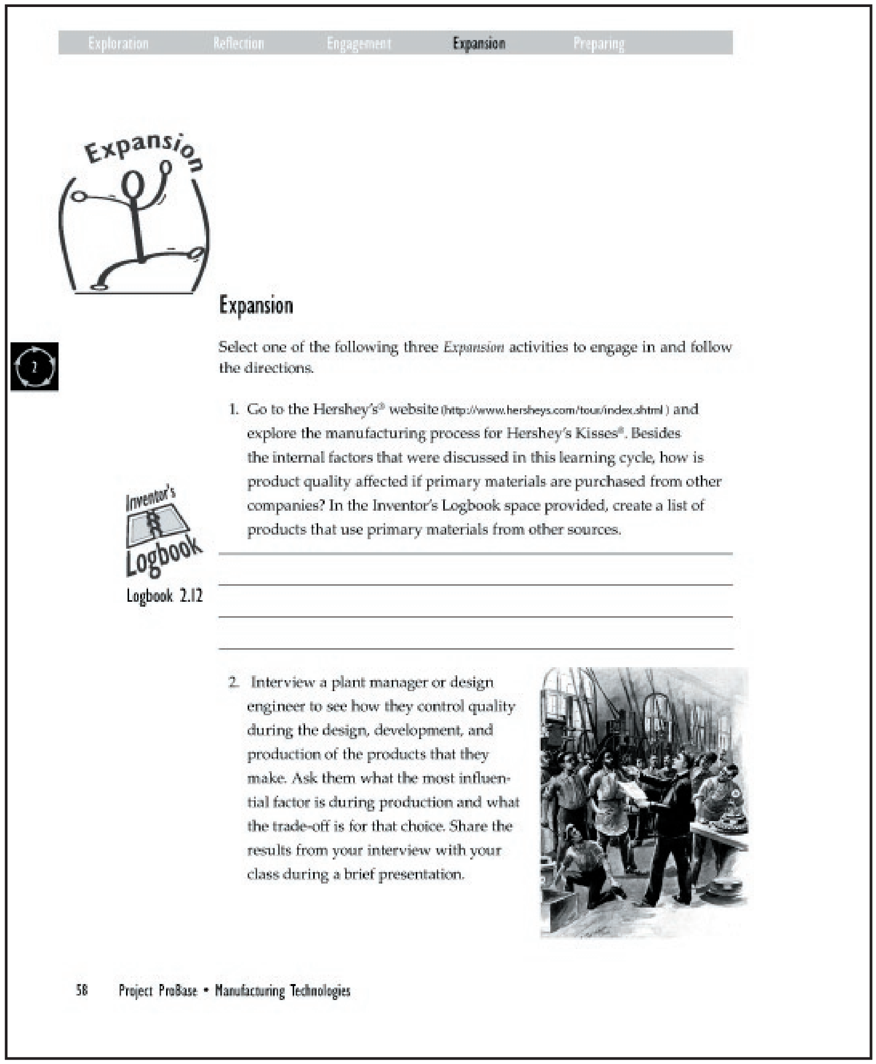
You may want to have students choose various soap colors and scents at this point so that materials may be purchased in advance.

Expansion

Although not required, these *Expansion* activities are designed to cause teams to delve deeper into the concepts explored in this learning cycle.

Students should select only one of the following options.

1. The students are asked to take a look at the Hershey plant tour provided on the Internet (http://www.hersheys.com/tour/index.shtml). Students will have an opportunity to see how a company buys primary materials from other sources. This web site also contains excellent examples of processes involved in the manufacturing process. If this web site is unavailable in the future, you should have your students search for other virtual tours of manufacturing facilities.



Exploration Reflection Engagement Expansion Preparing

Expansion

Select one of the following three *Expansion* activities to engage in and follow the directions.

1. Go to the Hershey's® website (http://www.hersheys.com/tour/index.shtml) and explore the manufacturing process for Hershey's Kisses®. Besides the internal factors that were discussed in this learning cycle, how is product quality affected if primary materials are purchased from other companies? In the Inventor's Logbook space provided, create a list of products that use primary materials from other sources.

Inventor's Logbook

Logbook 2.12

2. Interview a plant manager or design engineer to see how they control quality during the design, development, and production of the products that they make. Ask them what the most influential factor is during production and what the trade-off is for that choice. Share the results from your interview with your class during a brief presentation.

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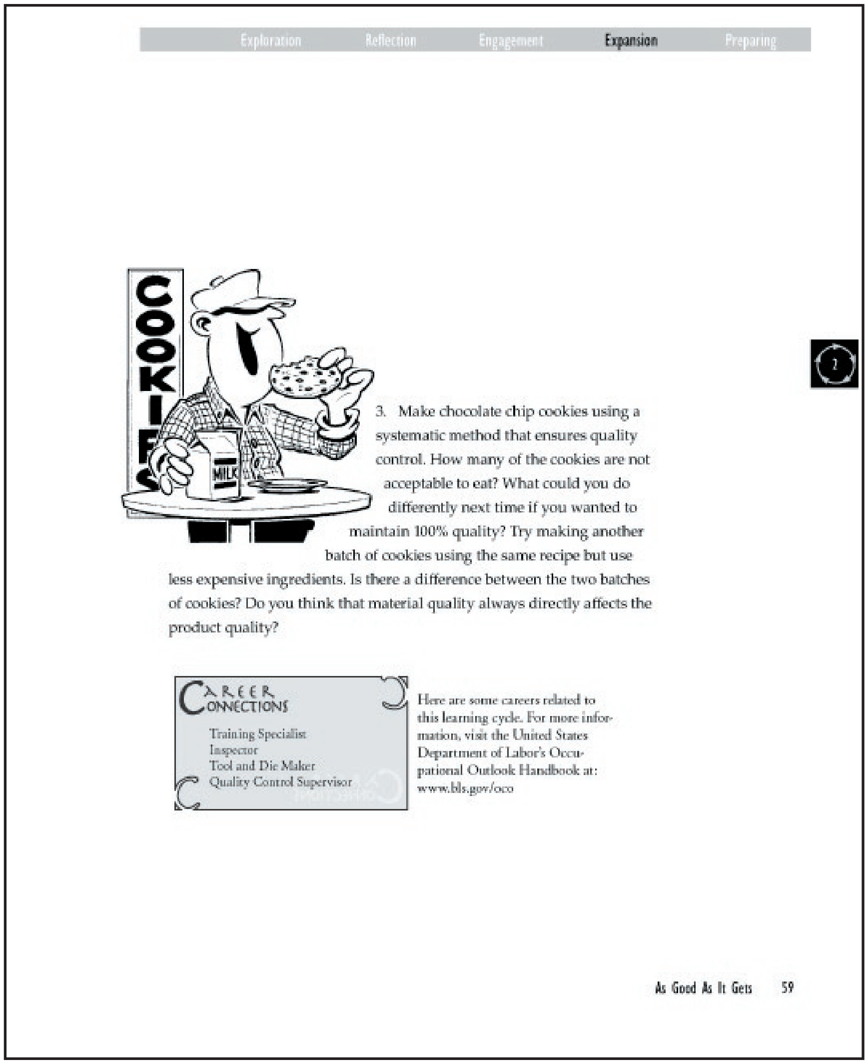
2. Students are required to interview someone who is directly involved with designing a product or facility. Students should create a list of questions for the interview based on what they learned during the learning cycle. Allow time in class for students to share their findings.



3. Make chocolate chip cookies using a systematic method that ensures quality control. How many of the cookies are not acceptable to eat? What could you do differently next time if you wanted to maintain 100% quality? Try making another batch of cookies using the same recipe but use less expensive ingredients. Is there a difference between the two batches of cookies? Do you think that material quality always directly affects the product quality?

CAREER CONNECTIONS

Training Specialist
Inspector
Tool and Die Maker
Quality Control Supervisor

Here are some careers related to this learning cycle. For more information, visit the United States Department of Labor's Occupational Outlook Handbook at: www.bls.gov/oco

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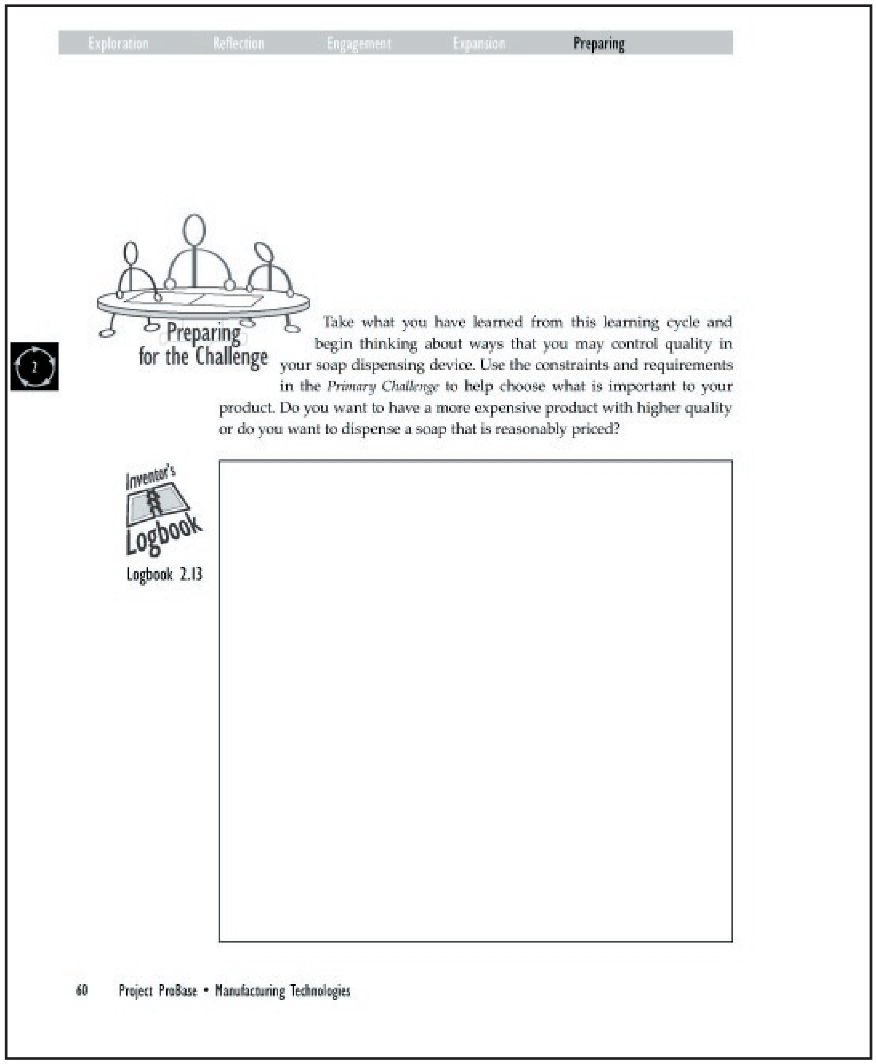
3. In this *Expansion* activity, students are required to compare the quality of materials by making cookies. This activity can be done inside or outside of class time. Students should choose one chocolate chip recipe and make two batches of chocolate chip cookies. One batch of cookies should be made with name brand chocolate chips and the ingredients listed in the recipe. The second batch of cookies should be made with a store brand chocolate chips and alternative ingredients such as an egg substitute. Students should generate a list of criteria that they will use to judge the quality of each type of cookie. Students should use this criteria to closely examine the quality difference of the cookies.

Preparing for the Challenge

Students are asked to begin thinking about factors that may affect and control quality in their soap dispensing machine. Students need to make decisions about the ingredients they intend to use for their liquid soap, so that they can be ordered to arrive in time for the *Primary Challenge.*


Exploration Reflection Engagement Expansion **Preparing**

Preparing for the Challenge

Take what you have learned from this learning cycle and begin thinking about ways that you may control quality in your soap dispensing device. Use the constraints and requirements in the *Primary Challenge* to help choose what is important to your product. Do you want to have a more expensive product with higher quality or do you want to dispense a soap that is reasonably priced?

Inventor's Logbook

Logbook 2.13

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Student Assessment

An assessment rubric has been developed for the *Exploration* and *Engagement* activities. Feel free to change this rubric to better suit your particular needs.

As Good As It Gets

Name: Date:

Element	Criteria				Points
	4	3	2	1	
Production Quality Control	Constructed an accurate “go/no go” jig; accurately categorized the paper clips in “go” and “no go” piles.	Constructed an accurate “go/no go” jig; paper clips were 95% accurate in “go” and “no go” piles.	Constructed an accurate “go/no go” jig; paper clips were 85% accurate in “go” and “no go” piles.	Constructed an accurate “go/no go” jig; paper clips were 75% accurate in “go” and “no go” piles	
Product Costs	Complete and accurate calculations recorded in Inventor’s Logbook; the cost of labor is calculated and recorded in the Inventor’s Logbook.	Complete but somewhat inaccurate calculations recorded in Inventor’s Logbook; the cost of labor is calculated and recorded in the Inventor’s Logbook.	Information missing and inaccurate calculations recorded in Inventor’s Logbook; the cost of labor is calculated and recorded in the Inventor’s Logbook.	Information missing and inaccurate calculations recorded in Inventor’s Logbook; the cost of labor is not calculated and recorded in the Inventor’s Logbook.	
Engagement	Identified parts of the soap dispensing device; created a complete diagram of how soap will be dispensed in Inventor’s Logbook; team assigned roles and worked extremely well together.	Identified parts of the soap dispensing device; created a somewhat complete diagram of how soap will be dispensed in Inventor’s Logbook; team assigned roles and worked well together.	Identified parts of the soap dispensing device; created an incomplete diagram of how soap will be dispensed in Inventor’s Logbook; team assigned roles but did not maintain them, had trouble working together.	Identified parts of the soap dispensing device; created an incomplete diagram of how soap will be dispensed in Inventor’s Logbook; did not assign roles and did not work well together.	
				Total Points	

2

Learning Cycle Three

3

Looping Through Design

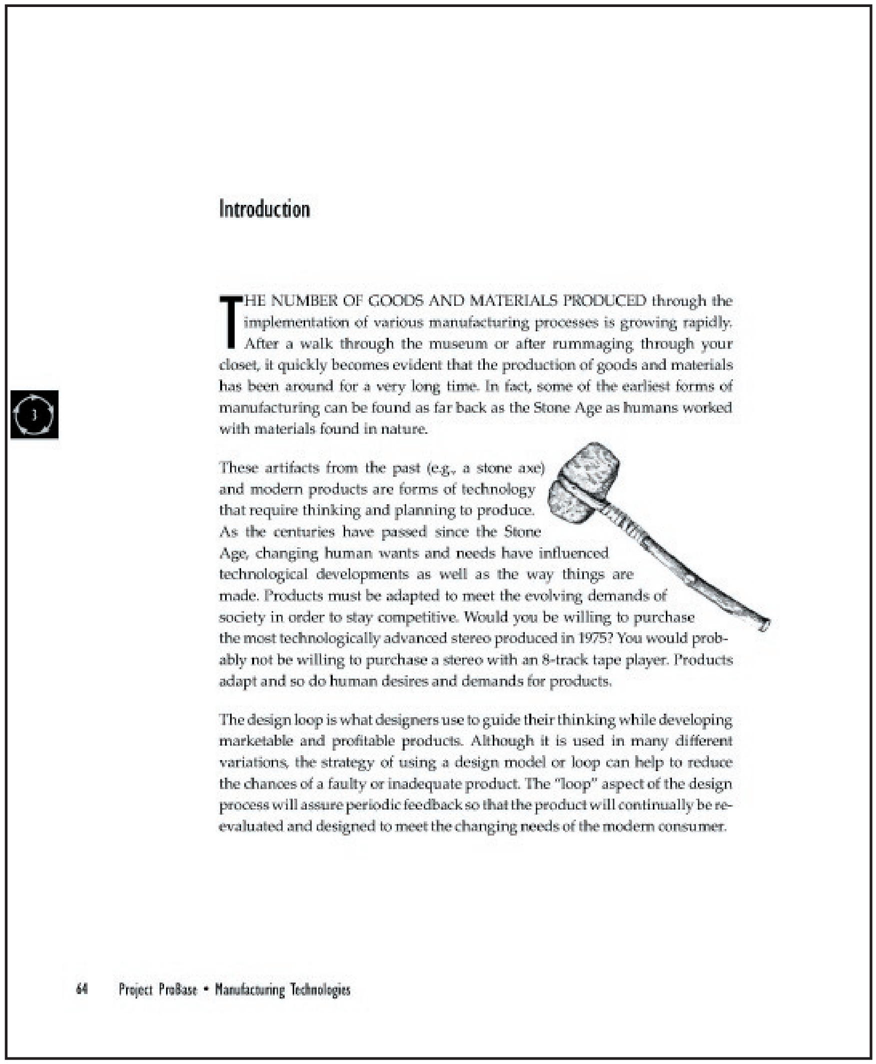
Looping Through Design

Introduction

In this learning cycle, the students will be focusing on applications of the engineering design model and a set of design principles that will guide their thinking as they solve technological problems. Many instructors have adapted unique forms of the engineering design model; however, they all tend to share common characteristics.

These characteristics are what make general problem solving models applicable to so many different situations. In this learning cycle, the design process will be applied to both a product and a facility in order to assist students in their planning for the *Primary Challenge*. Figure 1 illustrates one example of the engineering design model (sometimes called a design loop) promoted in *Standards for Technological Literacy* (ITEA, 2000, 2002).

This learning cycle will begin with an activity that causes students to explore factors that should be considered when designing a product. These ideas are then merged with a set of universal principles that can be applied to almost any design situation.



Introduction

THE NUMBER OF GOODS AND MATERIALS PRODUCED through the implementation of various manufacturing processes is growing rapidly. After a walk through the museum or after rummaging through your closet, it quickly becomes evident that the production of goods and materials has been around for a very long time. In fact, some of the earliest forms of manufacturing can be found as far back as the Stone Age as humans worked with materials found in nature.

These artifacts from the past (e.g., a stone axe) and modern products are forms of technology that require thinking and planning to produce. As the centuries have passed since the Stone Age, changing human wants and needs have influenced technological developments as well as the way things are made. Products must be adapted to meet the evolving demands of society in order to stay competitive. Would you be willing to purchase the most technologically advanced stereo produced in 1975? You would probably not be willing to purchase a stereo with an 8-track tape player. Products adapt and so do human desires and demands for products.

The design loop is what designers use to guide their thinking while developing marketable and profitable products. Although it is used in many different variations, the strategy of using a design model or loop can help to reduce the chances of a faulty or inadequate product. The "loop" aspect of the design process will assure periodic feedback so that the product will continually be re-evaluated and designed to meet the changing needs of the modern consumer.

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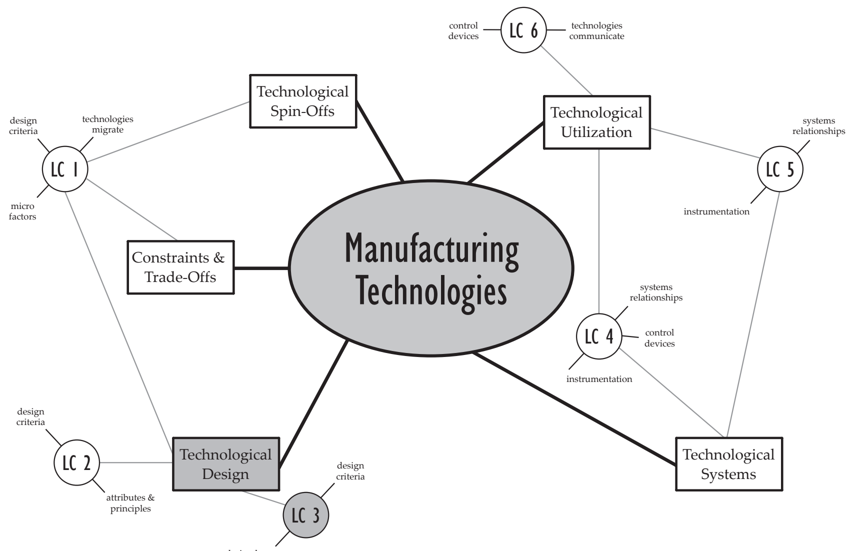
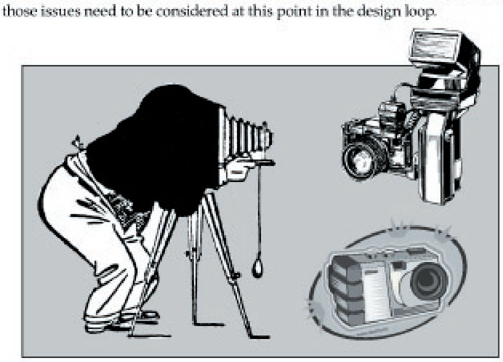
Manufacturing Technologies
Learning Cycle Three Concept Map



The design loop also helps designers solve problems in a logical and effective way by following a series of steps. Once a problem becomes apparent (through consumer feedback, defective parts, etc.), the problem is clearly defined. In other words, the complete nature of the problem is clarified and understood in order to create a complete solution.

After the problem is identified, the parameters involved in solving the problem are established and outlined. The parameters that guide the solution vary from product to product. Usually the parameters concern technical abilities or the available resources; for example, the type and amount of material available, the time constraints, the technical expertise needed, and the amount of money available often need to be considered. Other parameters may include the judgments, rules, and standards that need to be followed or met. For example, if a product needs to meet government standards for cleanliness, health, or safety, those issues need to be considered at this point in the design loop.



Looping Through Design 65

Experienced designers use a variety of processes as well as design principles when they develop solutions to various problems.

For the sake of simplicity, the students will focus on only five principles as they work to solve the *Primary Challenge* for this Learning Unit. The five design principles are function, efficiency, aesthetics, ergonomics, and anthropometrics. The *Exploration* phase of this learning cycle focuses on applying the design principles to product design while the *Engagement* phase engages students in a simulated manufacturing scenario where they apply the principles of design to a production facility.

Facility Requirements

Internet access is required for research of material/product processing. Large open areas (or room rearrangement) are necessary to allow for an assembly line.

Objectives and Essential Questions

1. Generate a viable solution to a technological problem using a design model (the design loop).

Essential Question 7b: To what extent can design problems be addressed through a series of generic procedures (a design loop)?

2. Identify and change a set of characteristics within a design as they pertain to a set of design principles (i.e., function, efficiency, aesthetics, ergonomics, and anthropometrics) and apply those characteristics to the development of a product and a system.

Essential Question 7c: What design criteria is typically considered when developing new technologies (i.e., marketability, safety, usability, reliability, cost, materials, etc.) and how do these influence the final product/system design?

Estimated number of 50-minute class periods: **4**

Suggested Daily Outline

Day One	Day Two
Exploration Design Principles	*Reflection, Engagement:* planning and organizing
Day Three	**Day Four**
Engagement: implementing assembly line	*Engagement Preparing for the Challenge*

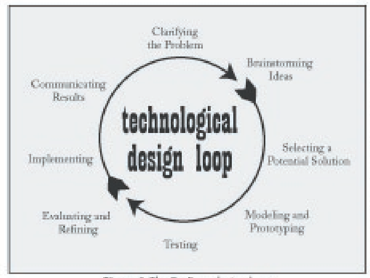


Figure 1. The ProBase design loop

After the problem and the parameters are clarified, the next step in the design loop is to begin to brainstorm and identify multiple potential solutions to the problem. A list of the different solutions should be developed and the characteristics which can be varied to better meet the problem pinpointed. From the list, the solution that best meets both the problem and the parameters is chosen (or a solution created from condensed and combined ideas). The selected solution is refined and fully developed and then tested and evaluated to determine if it meets the parameters and solves the problem. If refinements are necessary, they are made and the solution is tested and evaluated again. After the problem is believed to be solved, the item or product is made and presented. If other problems or feedback concerning the product occur, the loop starts over again. For an illustration of the design loop see Figure 1.

An excellent example of a product "passing" through the loop many times is the television. Think about how the television has changed over the years. Why have these changes taken place? Perhaps consumers have demanded improved performance (plasma screens), better usability (remote controls), or simply more attractive designs. Another possible reason could be that new technologies (satellites and digital cable) have impacted the over-all design. Regardless of the factors that "drive" the design changes in the television, a competitive marketplace requires adaptations and innovations in manufacturing.

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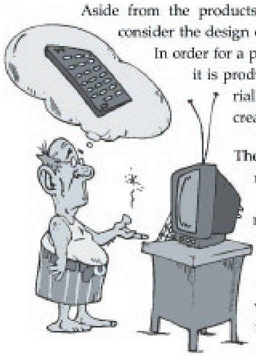
Equipment and Materials

Based on a class of 28 students:

- 5 different flashlights that range from simple to elaborate designs.
- 15-20 inexpensive flashlights that can be disassembled.
- Copies of the Design Principles Worksheet (in Appendix, page AH)



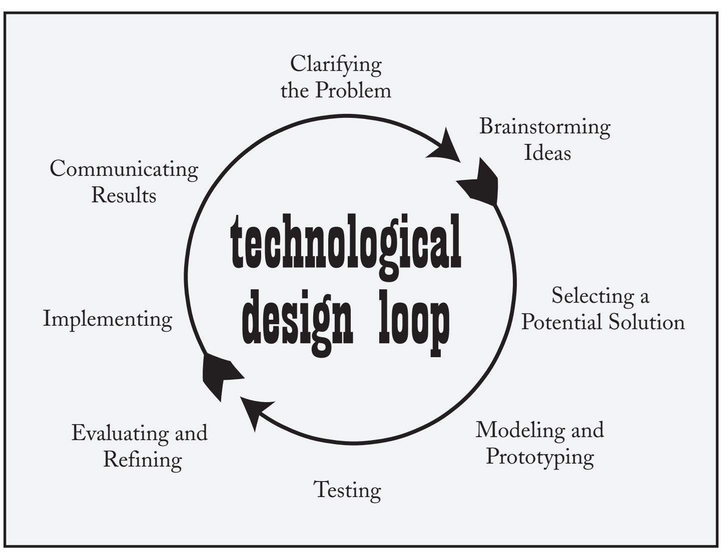
Aside from the products themselves, it is equally important to consider the design of manufacturing processes and facilities. In order for a product to change, the processes by which it is produced must also change. New tools, materials, and equipment enable manufacturers to create improved products.

The design loop is used while designing any manufacturing facility or process as well as the product. An important component of maximizing a company's profit is to reduce its production costs. Improvements made to the production or assembly of components can increase efficiency, limit or utilize waste more effectively, or provide new and innovative features to the products being manufactured.

Objectives

After completing this learning cycle, you will be able to:

1. Generate a viable solution to a technological problem using a design model (the design loop).
2. Identify and change a set of characteristics within a design as they pertain to a set of design principles and apply those concepts to the development of a product and a system.



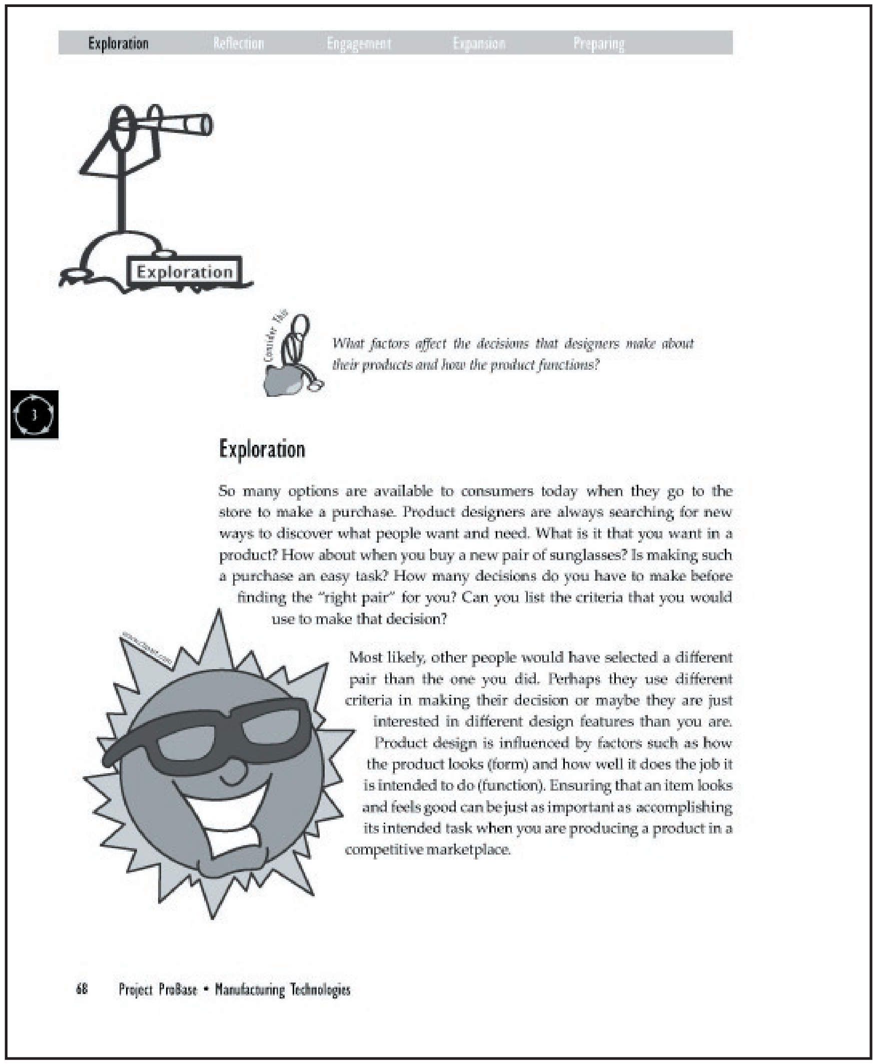
Exploration

This activity will focus on the engineering design model and the design principles that are used to guide the development of a product.

Teaching tips

It is important to have students think about the design model they will be using. Whether the design model is directly from *Standards for Technological Literacy* or developed from a different source, it should contain the following universal elements:

- Clarifying the problem
- Brainstorming ideas
- Selecting a potential solution
- Modeling and prototyping
- Testing
- Evaluating and refining
- Implementing
- Communicating results


Exploration Reflection Engagement Expansion Preparing

Exploration

Consider This

What factors affect the decisions that designers make about their products and how the product functions?

Exploration

So many options are available to consumers today when they go to the store to make a purchase. Product designers are always searching for new ways to discover what people want and need. What is it that you want in a product? How about when you buy a new pair of sunglasses? Is making such a purchase an easy task? How many decisions do you have to make before finding the "right pair" for you? Can you list the criteria that you would use to make that decision?

Most likely, other people would have selected a different pair than the one you did. Perhaps they use different criteria in making their decision or maybe they are just interested in different design features than you are. Product design is influenced by factors such as how the product looks (form) and how well it does the job it is intended to do (function). Ensuring that an item looks and feels good can be just as important as accomplishing its intended task when you are producing a product in a competitive marketplace.

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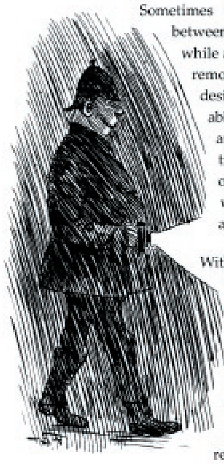
Teaching tips

Provide the students with five different types of flashlights. You may want to consider having your students bring flashlights from home so that you can have a wider variety. Students should be organized into teams of 2 or 3 and receive a copy of the Design Principles Worksheet to be completed as they work through this activity.



Sometimes designers face difficulties finding a balance between design characteristics that accomplish form while achieving functionality. Think about the modern remote control for a television. Most have been designed with buttons that are appealing and readable, and that are a size that is comfortable for the average user—but what about the ability to function? Consumers want an appealing device to operate their television equipment, but they also want everything to be universal and easy to use and understand.

With all of the equipment and hardware that has become a part of the home entertainment center, the electronics designers struggle to create remote control technologies that are universal and require minimal effort to operate while meeting the wants and needs of the consumer. Is your remote control "easy" for you to operate? Think of an elderly friend or relative. Do you think that they have the same desires for a remote control device that you have?

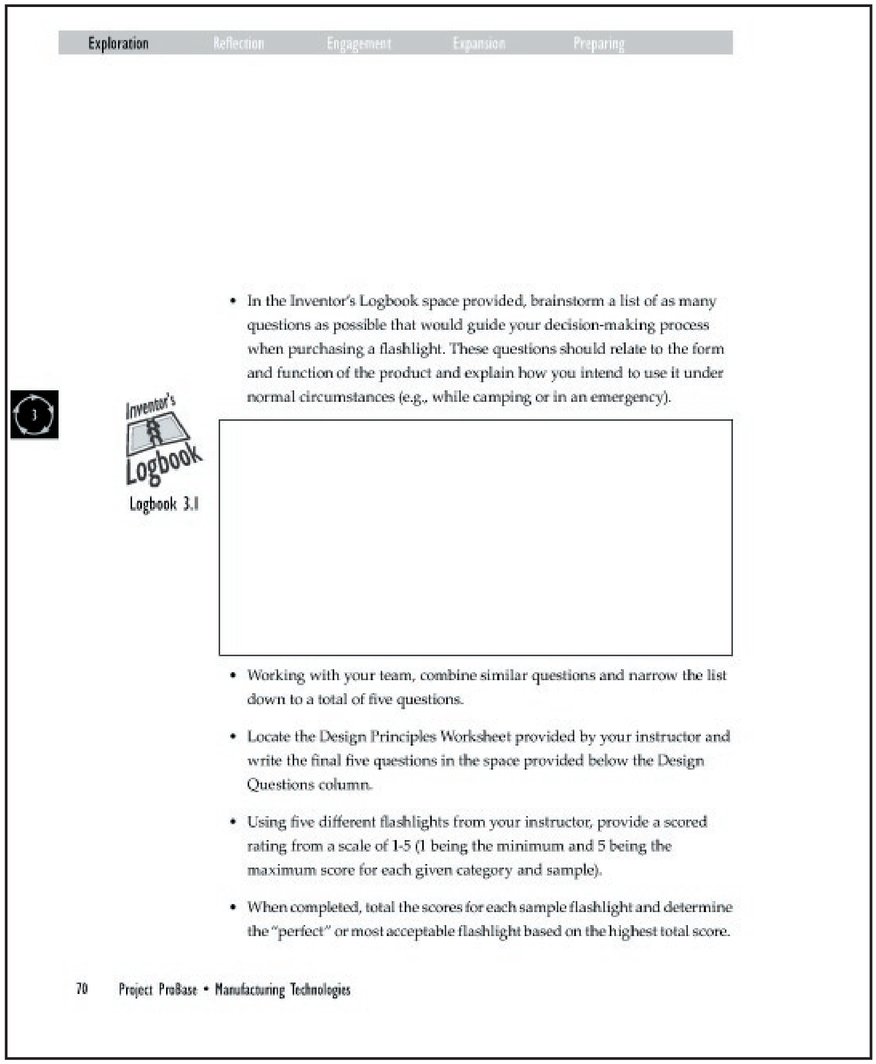
In this activity we are going to examine another product that has undergone tremendous changes in form and function. Your instructor has collected a variety of flashlights that range from very simple to very complex. Before looking at these flashlights, gather into small teams of two or three and complete the tasks on the following page.

Notes:

Ask your students probing questions that will cause them to think about the design principles (i.e., function, efficiency, aesthetics, ergonomics, and anthropometrics) as they generate their own set of questions.

For example, ask your students to consider questions that would cause someone to think about the function of a flashlight, or the ergonomics built into the designs that they are working with. Example questions are provided.

- Does the flashlight use rechargeable batteries?
- Does the flashlight adequately provide light in a darkened space?
- Does the flashlight work without failure under various conditions (water, cold, heat)?


Exploration Reflection Engagement Expansion Preparing

- In the Inventor's Logbook space provided, brainstorm a list of as many questions as possible that would guide your decision-making process when purchasing a flashlight. These questions should relate to the form and function of the product and explain how you intend to use it under normal circumstances (e.g., while camping or in an emergency).

Inventor's Logbook

Logbook 3.1

- Working with your team, combine similar questions and narrow the list down to a total of five questions.
- Locate the Design Principles Worksheet provided by your instructor and write the final five questions in the space provided below the Design Questions column.
- Using five different flashlights from your instructor, provide a scored rating from a scale of 1-5 (1 being the minimum and 5 being the maximum score for each given category and sample).
- When completed, total the scores for each sample flashlight and determine the "perfect" or most acceptable flashlight based on the highest total score.

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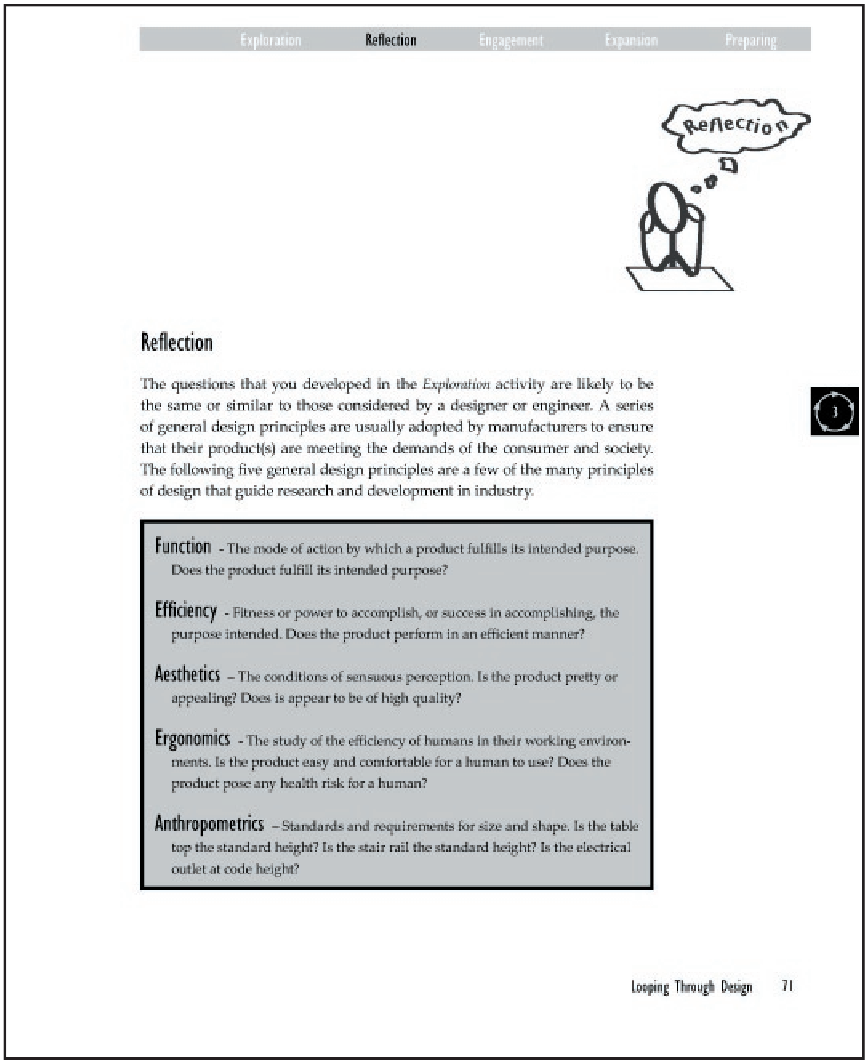
- Is the flashlight attractive?
- Is the flashlight comfortable to hold?
- Is the size and shape of the flashlight consistent with what a flashlight should be?
- Does the flashlight have the potential to attract the attention of prospective buyers?

After developing questions of this type, students should begin to assess each of the sample flashlights based on these questions to determine the one that best fits their needs as a consumer.


Exploration Reflection Engagement Expansion Preparing

Reflection

Reflection

The questions that you developed in the *Exploration* activity are likely to be the same or similar to those considered by a designer or engineer. A series of general design principles are usually adopted by manufacturers to ensure that their product(s) are meeting the demands of the consumer and society. The following five general design principles are a few of the many principles of design that guide research and development in industry.

Function - The mode of action by which a product fulfills its intended purpose. Does the product fulfill its intended purpose?

Efficiency - Fitness or power to accomplish, or success in accomplishing, the purpose intended. Does the product perform in an efficient manner?

Aesthetics – The conditions of sensuous perception. Is the product pretty or appealing? Does is appear to be of high quality?

Ergonomics - The study of the efficiency of humans in their working environments. Is the product easy and comfortable for a human to use? Does the product pose any health risk for a human?

Anthropometrics – Standards and requirements for size and shape. Is the table top the standard height? Is the stair rail the standard height? Is the electrical outlet at code height?

Looping Through Design 71

Reflection

Students will need time to review the five design principles in order to categorize the questions they have developed. The five design principles along with brief descriptions are provided below. The Student Guide defines each of these principles; however, you should elaborate on how they apply to both a product and a facility. Make clear the fact that many other design principles exist (form, reliability, safety, durability, etc.), but the five categories being used are very universal and applicable to the *Primary Challenge.*

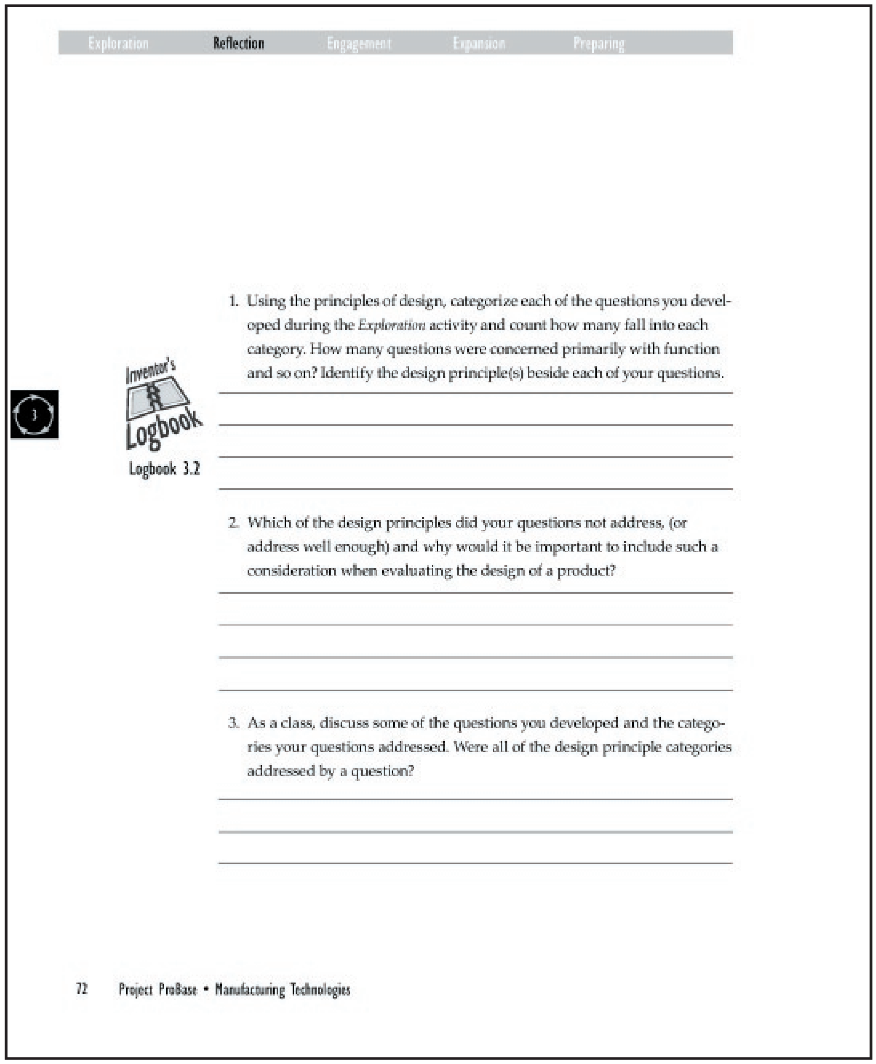
Function
The extent to which a device or process fulfills its intended purpose. For example, sunglasses come in a variety of different styles, but they must be able to block ultraviolet rays and fit a human face.

Efficiency
Ability to accomplish a purpose or function with minimal resources (e.g., time, energy, effort). For example, a portable CD player should be able to maximize its power supply so that recharging or battery replacement is minimized. Another example is magazine companies always looking for ways to print materials with greater speed and fewer materials. Automation can also benefit the efficiency rating of almost any manufacturing process.

Aesthetics
The concern here is for visual appeal. Clothing designers compete to create the most attractive clothing that will appeal to consumers and fashion retailers. Aesthetics can even be important for facilities. Small manufacturers that compete to supply a larger manufacturer with a component or product need to make sure their facilities are neat, clean, and well organized (if they hope to attract business and retain employees).

Ergonomics
The efficiency and safety of humans in their working environments. Ergonomics involve careful consideration of interactions between the human body and the physical world or between humans and the devices that they use (remember the flashlight). For example, the design of a chair should account for the natural curvature of the back. When humans are involved with manufacturing, the operation of machines should be designed to minimize any unnecessary physical strain or tension.

Anthropometrics
Standards and requirements that allow the product to fit the human spectrum or condition. Anthropometrics is a contemporary term that has applied to products and systems for a very long time. For example, a baby crib must have specific widths between slats to ensure safety, and the size and shape of electrical plugs must be designed according to standards to ensure that they can function in a standard outlet. The use of materials is also an important part of anthropometrics. Specific requirements for products help to ensure safety, reliability, and in some cases quality. Most of the tools and machines in manufacturing facilities have been designed according to a set of standards to insure interchangeability of components in the event of a breakdown or upgrade.


Exploration Reflection Engagement Expansion Preparing

Inventor's Logbook

Logbook 3.2

1. Using the principles of design, categorize each of the questions you developed during the *Exploration* activity and count how many fall into each category. How many questions were concerned primarily with function and so on? Identify the design principle(s) beside each of your questions.

2. Which of the design principles did your questions not address, (or address well enough) and why would it be important to include such a consideration when evaluating the design of a product?

3. As a class, discuss some of the questions you developed and the categories your questions addressed. Were all of the design principle categories addressed by a question?

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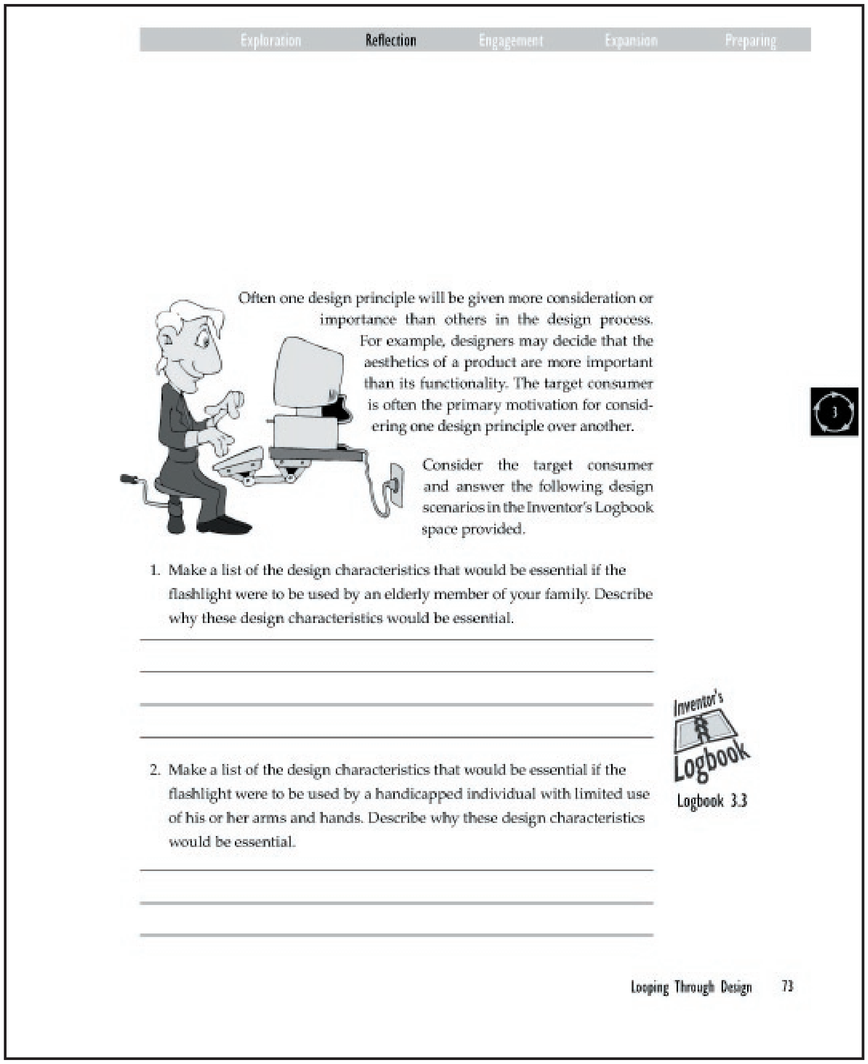


Exploration Reflection Engagement Expansion Preparing

Often one design principle will be given more consideration or importance than others in the design process. For example, designers may decide that the aesthetics of a product are more important than its functionality. The target consumer is often the primary motivation for considering one design principle over another.

Consider the target consumer and answer the following design scenarios in the Inventor's Logbook space provided.

1. Make a list of the design characteristics that would be essential if the flashlight were to be used by an elderly member of your family. Describe why these design characteristics would be essential.

Inventor's Logbook

Logbook 3.3

2. Make a list of the design characteristics that would be essential if the flashlight were to be used by a handicapped individual with limited use of his or her arms and hands. Describe why these design characteristics would be essential.

Looping Through Design 73

Teaching Tips

Require students to complete their worksheets. Remind them to identify the design principle each of their questions addresses. After providing some time for students to respond in their text, have them share some of the questions that they developed. They should also identify which design principle the question is addressing.

Allow students time to answer or assign as homework the following questions in their Inventor's Logbook space provided in their text:

1. Make a list of the design characteristics that would be essential if the flashlight were to be used by an elderly member of your family. Describe why these design characteristics would be essential.
   Responses to this question should consider the needs of an elderly person. For example, the grip and power button should be easily manipulated for those with arthritis.

2. Make a list of the design characteristics that would be essential if the flashlight were to be used by a handicapped individual with limited use of his or her arms or hands. Describe why these design characteristics would be essential.
   Students should again consider the specific needs of a handicapped person with limited use of his or her arms and hands.

3

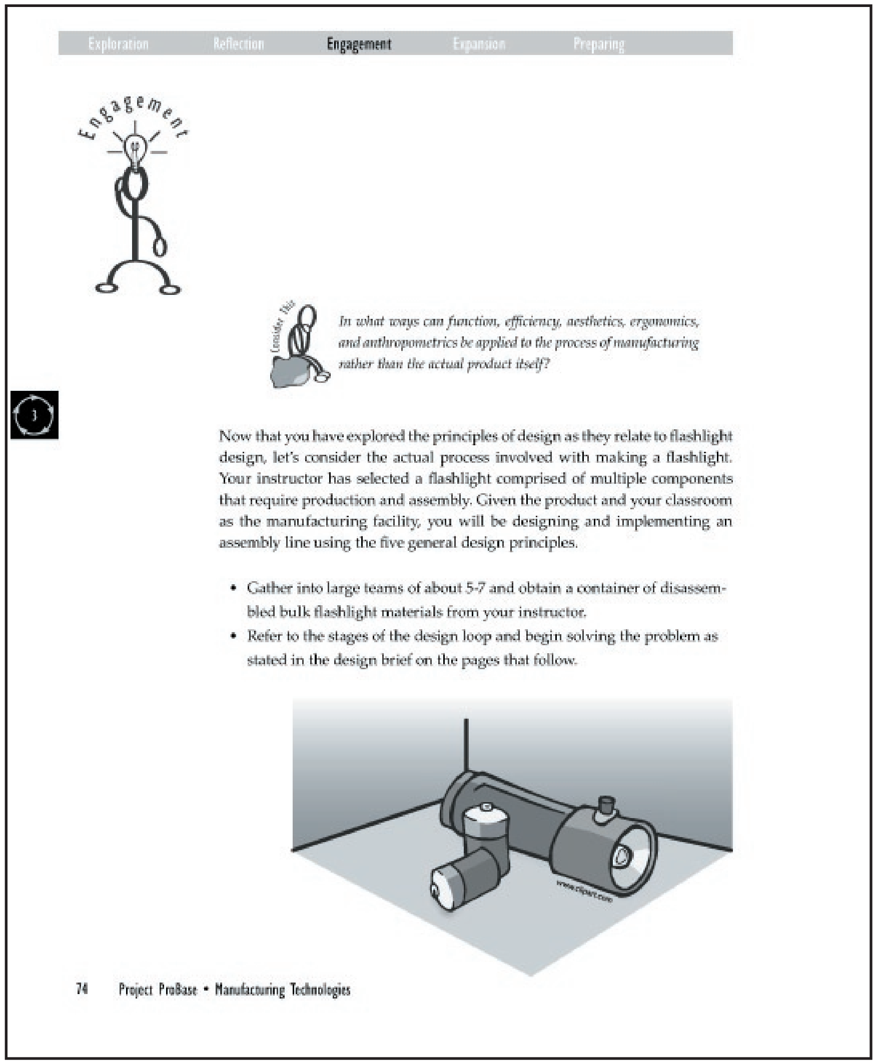
Engagement

This activity is focused on engineering design principles that guide the development of manufacturing facilities.

Teaching Tips

You should select a flashlight that is relatively simple in its design, easily dissembled and reassembled, and low in cost. The students will be developing a human assembly line to assemble the flashlight of your choosing.

The class should be divided into teams of 5-7 students. Each team should receive one disassembled flashlight. From the subcomponents and the constraints listed in the Student Guide, students are to design and create a human assembly line that considers the five basic design principles. Additional flashlights will be needed (of the same construction type) so that teams can actually implement their final solution in the assembly line.


Exploration Reflection Engagement Expansion Preparing

Engagement

Consider This

In what ways can function, efficiency, aesthetics, ergonomics, and anthropometrics be applied to the process of manufacturing rather than the actual product itself?

Now that you have explored the principles of design as they relate to flashlight design, let's consider the actual process involved with making a flashlight. Your instructor has selected a flashlight comprised of multiple components that require production and assembly. Given the product and your classroom as the manufacturing facility, you will be designing and implementing an assembly line using the five general design principles.

- Gather into large teams of about 5-7 and obtain a container of disassembled bulk flashlight materials from your instructor.
- Refer to the stages of the design loop and begin solving the problem as stated in the design brief on the pages that follow.

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Teaching Tips

The engineering design model used during the *Exploration* phase should be used to solve this problem. This will enable students to understand how the design model can be used while designing facilities. This experience will help your students design the solution for their *Primary Challenge*.

The student text asks them to solve the problem using the text below:

Design Brief

To: Student Design Teams
From: Management
Re: Facility Design

Our company recently purchased a new building with the intention of dividing it into two major areas. One area would be dedicated to the actual production of the subcomponents and the second is reserved for the assembly of these components after they have been produced. We are giving your design team the challenge of creating a facility for our flashlight manufacturing company.

We, as a management team, have determined that we must address many factors before constructing the assembly portion of our facility. We hope to eventually automate the entire process, but we first must determine the general flow and order in which the subcomponents are assembled before investing the time and money into the equipment.

There are many companies in the world competing for the production of flashlights and, as management, we are very concerned about designing our facility to be as efficient as possible. Because of your experience with the basic design principles, your team has been hired to provide a solution to this problem. Specific details are provided on the following page.

Thanks and good luck!

page 1 of 2
Management

Teaching Tips

Essentially, the students will experiment with various assembly techniques until they determine the optimum assembly system for these flashlights. After they have completed this exercise, you should lead a discussion of the differences between custom production, mass production, and custom/mass production. You will want to point out the benefits and drawbacks of each, the limitations of each, and the reasons for selecting one system over the others.

Design Brief

To: Student Design Teams
From: Management
Re: Facility Design

The design loop can be used in a variety of ways to solve many different technological problems. Though this model is found in various forms, applying it helps to insure that a designer is taking into account the many different factors that influence design and the success of a final product. (Return to Figure 1 on page 68 to better understand how designers implement the design loop.)

You will be using this process to generate your solutions to the facility design. The five basic design principles should guide your research and influence your decisions about the proposed and implemented solutions. The following constraints and limitations must first be considered before solving this problem:

1. The assembly line must consist of individual cells (or stations) through which the product must pass as it is being assembled.

2. Since the cost of producing the line is expensive, each cell should consist of a person(s) rather than a machine to represent the automation.

3. The research portion of the design loop should take into consideration the five design principles, as they would apply to the facility design.

4. At least two plausible solutions to the flashlight assembly problem must be proposed by the team before you are allowed to test your process design.

5. The feedback stage of the cycle must include references to how each design principle could be improved within the facility design. These responses must be recorded in the Inventor's Logbook space at the completion of this activity.

page 2 of 2

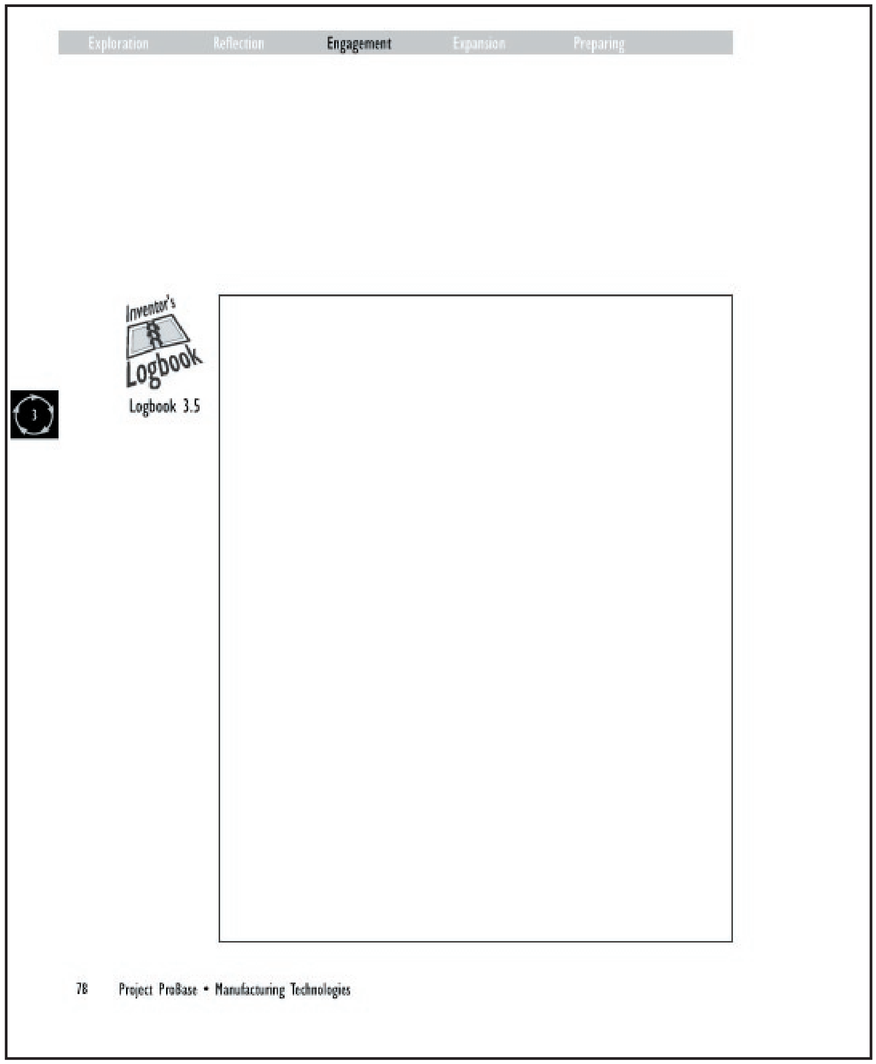
Record (in detail) the design process you followed while solving the problem in the Inventor's Logbook spaces provided on the next two pages.

Inventor's Logbook

Logbook 3.4

Notes:

Notes:


Exploration Reflection Engagement Expansion Preparing

Inventor's Logbook

Logbook 3.5

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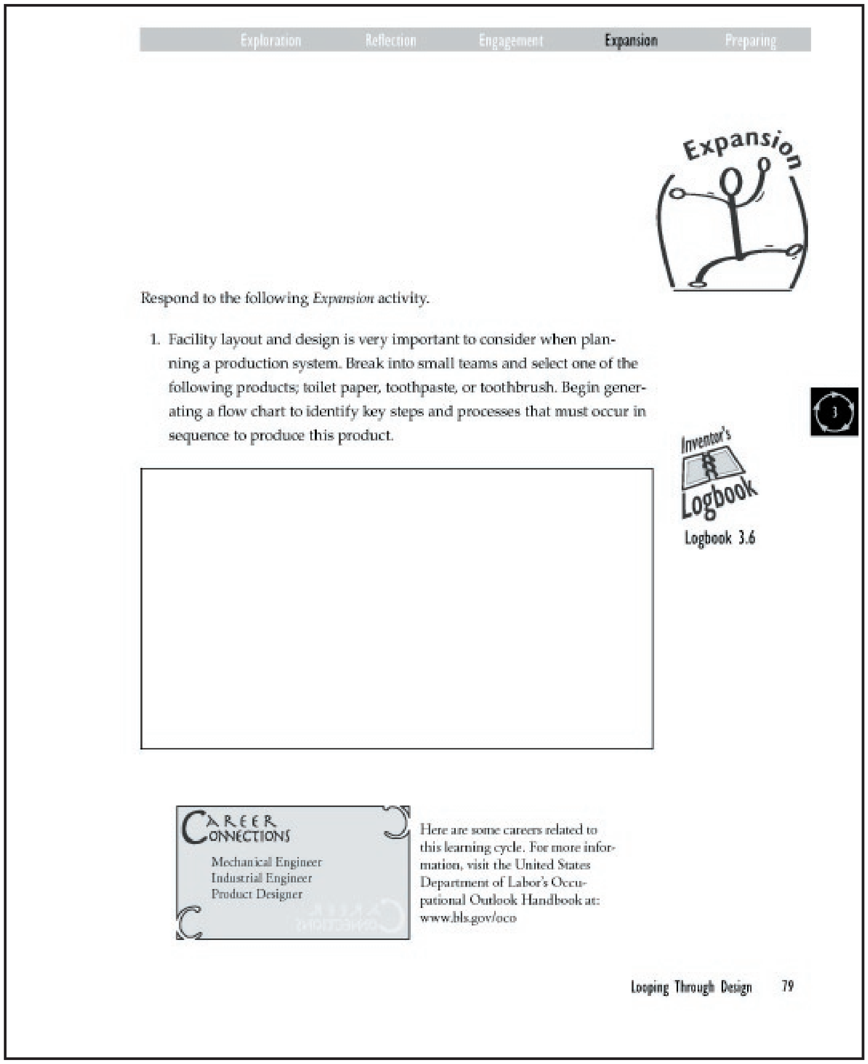

Exploration Reflection Engagement Expansion Preparing

Expansion

Respond to the following *Expansion* activity.

1. Facility layout and design is very important to consider when planning a production system. Break into small teams and select one of the following products; toilet paper, toothpaste, or toothbrush. Begin generating a flow chart to identify key steps and processes that must occur in sequence to produce this product.

Inventor's Logbook

Logbook 3.6

CAREER CONNECTIONS

Mechanical Engineer
Industrial Engineer
Product Designer

Here are some careers related to this learning cycle. For more information, visit the United States Department of Labor's Occupational Outlook Handbook at: www.bls.gov/oco

Looping Through Design 79

Expansion

Although not required, these *Expansion* activities are designed to cause teams to delve deeper into the concepts explored in this learning cycle.

1. In this activity, students will identify the characteristics that their dispensing device must have to accommodate the process and the variables involved (fragrance, color, label) for their *Primary Challenge.*

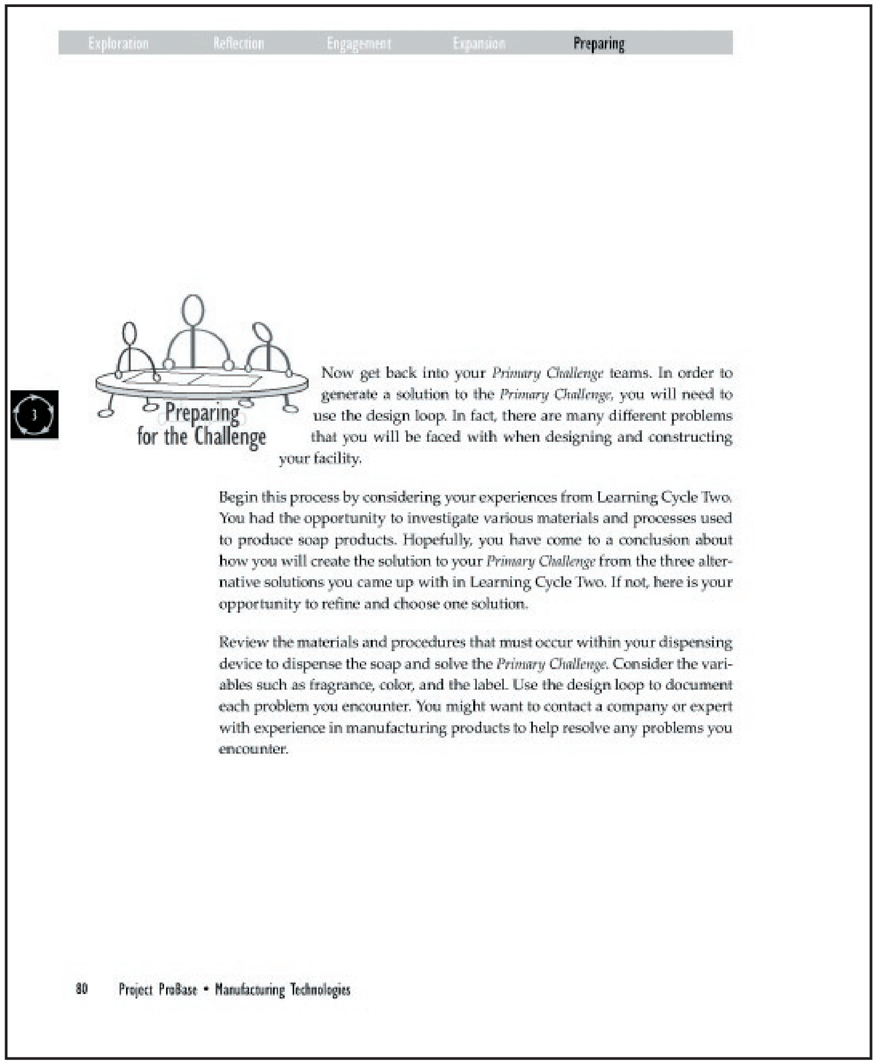
   The use of an engineering design model (e.g., defining the problem, generating potential solutions to the problem, selecting the most viable solution, making a model or prototype, evaluating the model/prototype, and presenting the results) should be used to guide their thinking as they encounter different problems and issues.

   Solutions should take on the form of a flow chart, which uses boxes and arrows to show the flow for dispensing liquid soap. Students must identify what materials they are going to use and what specific things must happen to these materials to reach a final product. The flow chart should be very descriptive and contain information about what must happen to the materials and the dispensing device within each component or cell.

2. This activity will reinforce the engineering design model and the planning of production processes. In teams of three, students are asked to select a product (toilet paper, toothpaste, or toothbrush) and create a flow chart to identify key steps and processes that must occur in sequence to produce the selected product.

Preparing for the Challenge

Progress on a solution to the *Primary Challenge* is an important consideration of this learning cycle. Upon completing the activities, it is very important for the *Primary Challenge* teams to have completed a flow chart that represents the processes they will use to dispense liquid soap.



Preparing for the Challenge

Now get back into your *Primary Challenge* teams. In order to generate a solution to the *Primary Challenge*, you will need to use the design loop. In fact, there are many different problems that you will be faced with when designing and constructing your facility.

Begin this process by considering your experiences from Learning Cycle Two. You had the opportunity to investigate various materials and processes used to produce soap products. Hopefully, you have come to a conclusion about how you will create the solution to your *Primary Challenge* from the three alternative solutions you came up with in Learning Cycle Two. If not, here is your opportunity to refine and choose one solution.

Review the materials and procedures that must occur within your dispensing device to dispense the soap and solve the *Primary Challenge*. Consider the variables such as fragrance, color, and the label. Use the design loop to document each problem you encounter. You might want to contact a company or expert with experience in manufacturing products to help resolve any problems you encounter.

Exploration | Reflection | Engagement | Expansion | **Preparing**

The following questions might help you refine your solution. Answer them in the Inventor's Logbook spaces provided:

1. What steps must occur for raw materials to enter the machine and for a completed product to exit the vending machine?

   a. Create a flow chart documenting this process.

Inventor's Logbook

Logbook 3.7

Looping Through Design 81

Notes:

Student Assessment

An assessment rubric has been developed for the *Exploration* and *Engagement* activities. Feel free to change this rubric to better suit your particular needs. In addition, it will be your prerogative as to how you assess the answers to the questions and other required tasks that students placed in their Inventor's Logbook spaces.

b. What must take place physically (to the material and/or product) as it passes through the vending machine?

c. What safety considerations must be made to assure the safety of the user and the safety of the machine?

2. After considering the flow process of your vending machine, with what particular process are you most concerned?

Looping Through Design

Element	Criteria				Points
	4	3	2	1	
Overall Design Model: applications of the generic stages within the design process.	Demonstrates exceptional applications of the design model in solving problems in learning cycle.	Demonstrates reasonable applications of the design model in solving problems in learning cycle.	Demonstrates minimal applications of the design model in solving problems in learning cycle.	Demonstrates poor applications of the design model in solving problems in learning cycle.	
Exploration/Reflection Design Principles: (product) applications of each design principle	Demonstrates exceptional applications of design principles in product design.	Demonstrates reasonable applications of design principles in product design.	Demonstrates minimal applications of design principles in product design.	Demonstrates poor applications of design principles in product design.	
Engagement Design Principles: applications of each design principle through researching & documenting assembly facility design	Demonstrates exceptional applications of design principles in facility design, through research documentation.	Demonstrates reasonable applications of design principles in facility design, through research documentation.	Demonstrates minimal applications of design principles in facility design, through research documentation.	Demonstrates poor applications of design principles in facility design, through research documentation.	
Engagement Process Design: flow chart containing cells of a process to assemble a flashlight	Developed an exceptional flow chart and descriptions.	Developed a good flow chart and descriptions.	Developed a reasonable flow chart and descriptions.	Developed a poor flow chart and descriptions.	
Engagement Process Design: technical illustrations of facility layout	Developed exceptional technical illustrations of the facility layout.	Developed good technical illustrations of the facility layout.	Developed reasonable technical illustrations of the facility layout.	Developed poor technical illustrations of the facility layout.	
Expansion: *Primary Challenge* solution and flow chart	Developed exceptional flow chart for the *Primary Challenge.*	Developed good flow chart for *Primary Challenge.*	Developed reasonable flow chart for *Primary Challenge.*	Developed poor flow chart for *Primary Challenge.*	
				Totals	

3

Learning Cycle Four

In Control

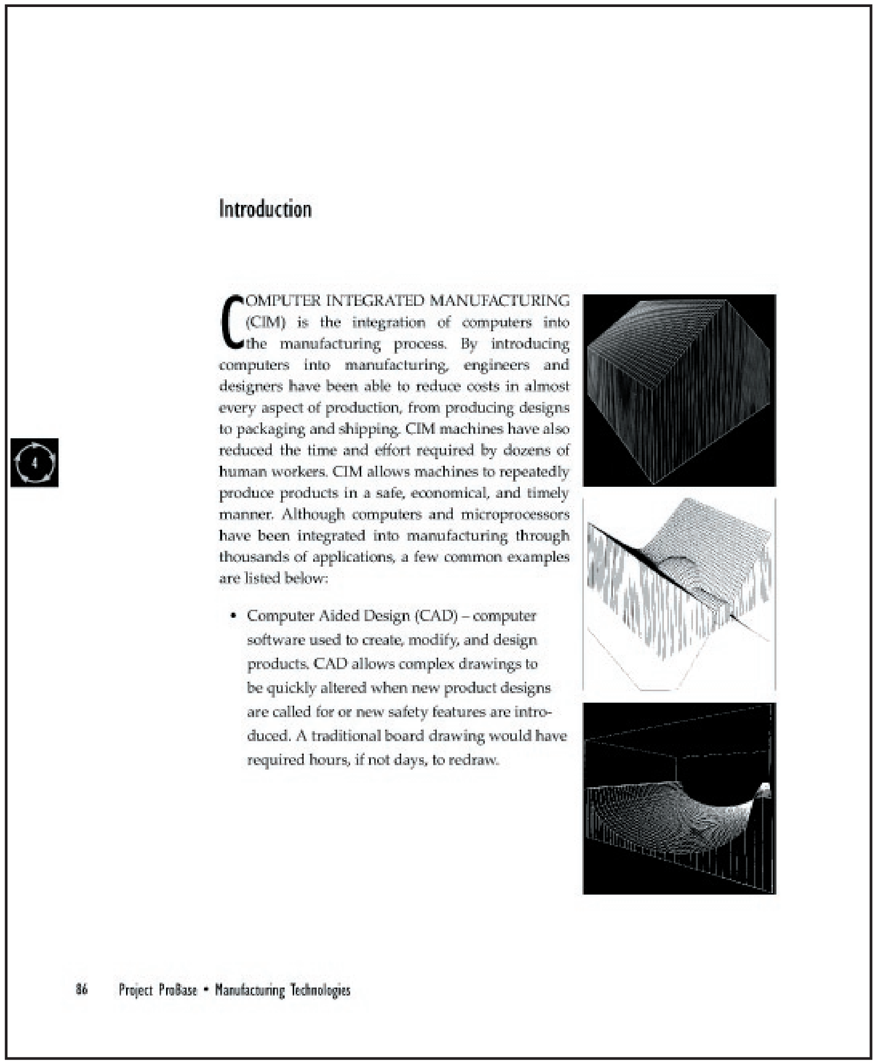
4

In Control

Introduction

In this learning cycle, students will be focusing on the use of microprocessors that are used in computer integrated manufacturing environments. This learning cycle will introduce students to the BASIC Stamp® HomeWork Board™ and a standard servo motor.

Students will attach the servo to the HomeWork Board's project platform and run a set of programs that control the movements of the servo. Students will use this knowledge during the *Expansion* phase as they are challenged to create a valve to control the flow of water using the servo motor.



Introduction

COMPUTER INTEGRATED MANUFACTURING (CIM) is the integration of computers into the manufacturing process. By introducing computers into manufacturing, engineers and designers have been able to reduce costs in almost every aspect of production, from producing designs to packaging and shipping. CIM machines have also reduced the time and effort required by dozens of human workers. CIM allows machines to repeatedly produce products in a safe, economical, and timely manner. Although computers and microprocessors have been integrated into manufacturing through thousands of applications, a few common examples are listed below:

- Computer Aided Design (CAD) – computer software used to create, modify, and design products. CAD allows complex drawings to be quickly altered when new product designs are called for or new safety features are introduced. A traditional board drawing would have required hours, if not days, to redraw.

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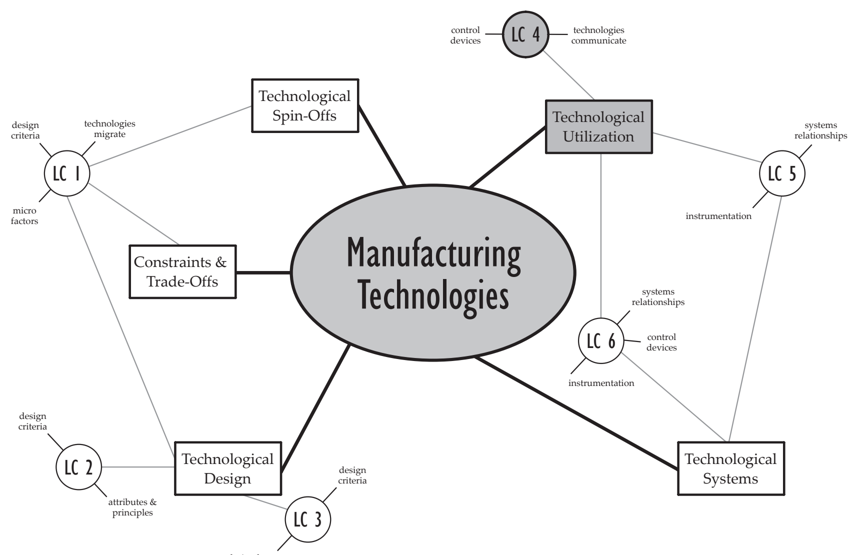
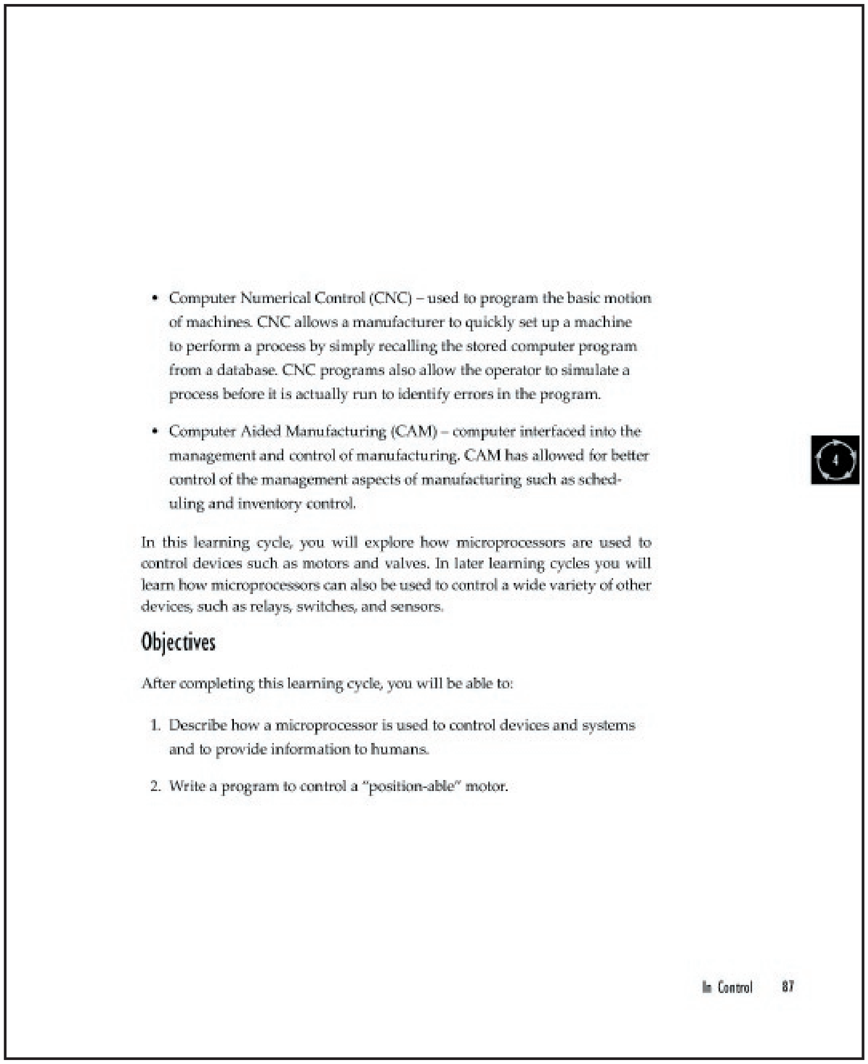
Objectives and Essential Questions

1. Describe how a microprocessor is used to control devices and systems and to provide information to humans.
   Essential Question 9b: How do technologies communicate with one another and provide information to humans?

2. Write a program to control a "position-able" motor.
   Essential Question 9a: How are technologies used to control devices and systems?

Manufacturing Technologies
Learning Cycle Four Concept Map





- Computer Numerical Control (CNC) – used to program the basic motion of machines. CNC allows a manufacturer to quickly set up a machine to perform a process by simply recalling the stored computer program from a database. CNC programs also allow the operator to simulate a process before it is actually run to identify errors in the program.
- Computer Aided Manufacturing (CAM) – computer interfaced into the management and control of manufacturing. CAM has allowed for better control of the management aspects of manufacturing such as scheduling and inventory control.

In this learning cycle, you will explore how microprocessors are used to control devices such as motors and valves. In later learning cycles you will learn how microprocessors can also be used to control a wide variety of other devices, such as relays, switches, and sensors.

Objectives

After completing this learning cycle, you will be able to:

1. Describe how a microprocessor is used to control devices and systems and to provide information to humans.
2. Write a program to control a "position-able" motor.

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Facility Requirements

No special facility requirements are required as long as students have access to computers and a place to design and build their valve system.

Equipment and Materials

Based on a class of 28 students (teams of 3-4 students):

(7) BASIC Stamp Homework Boards - suggested source: Parallax, Inc. (www.parallax.com), part # 28158

(7) Standard servo motors - suggested source: Parallax, Inc. (www.parallax.com), part # 900-00005

(7) BASIC Stamp serial programming cable - suggested source: Parallax, Inc. (www.parallax.com), part # 800-00003

BASIC Stamp Editor® version 2.1 software

(7) 470 Ω Resistors (yellow-violet-brown)

(7) LEDs

(7) 3-pin Male/Male headers

(11) Jumper wires

(7) 9V Batteries

(7) 2 AA battery packs

Small tension springs

Small machine screws

(7) Short lengths of wood

Ring stands and clamps from the chemistry department

cont'd on following page:

The following materials can be varied, as long the tubing and rod chosen fits in the chosen t-connector. You may want to obtain a variety of each and have the students choose among them:

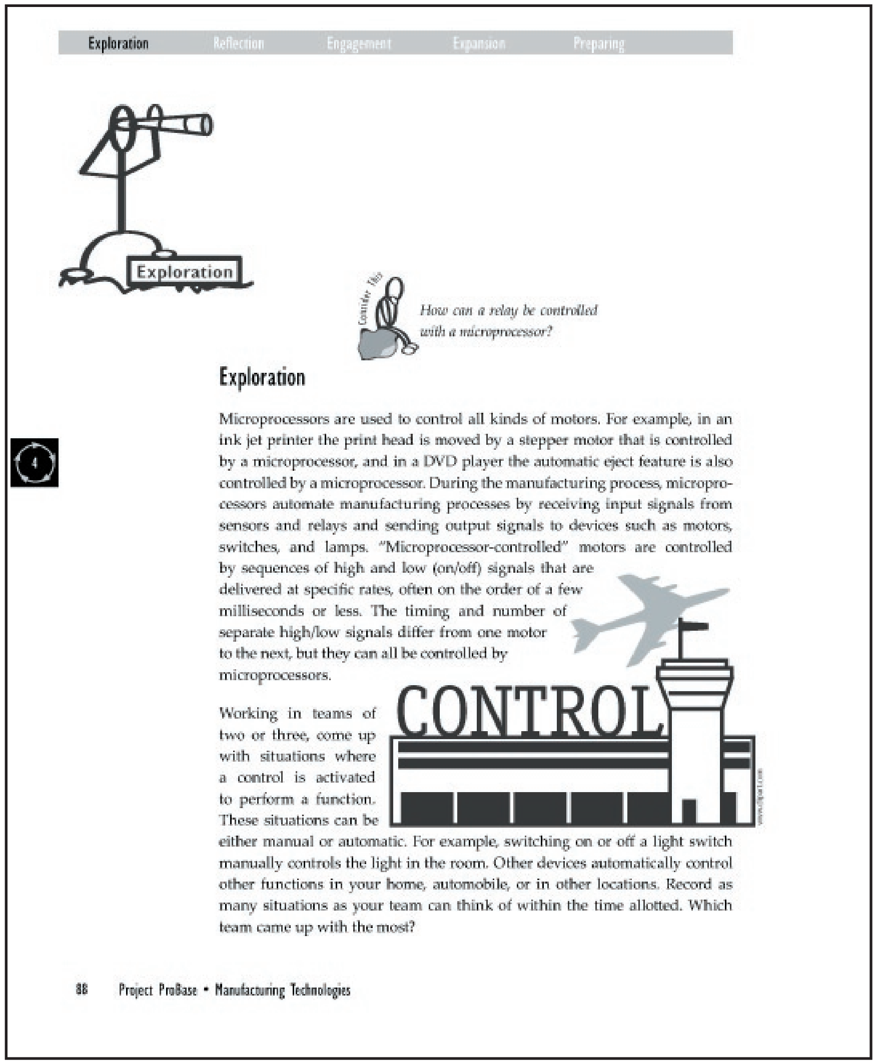
- Flexible rubber tubing
- (7) T-Connectors (can be obtained from Kelvin)
- (7) Rods: wood, metal, or other material
- (14) Containers to hold water

Students will also need access to a personal computer to enter the program into the BASIC Stamp Editor software and to connect their HomeWork Board.

> Estimated number of 50-minute class periods: **4**

Suggested Daily Outline

Day One	Day Two
Exploration, Reflection	*Engagement*
Day Three	**Day Four**
Engagement	*Engagement, Preparing for the Challenge*



Exploration | Reflection | Engagement | Expansion | Preparing

How can a relay be controlled with a microprocessor?

Exploration

Microprocessors are used to control all kinds of motors. For example, in an ink jet printer the print head is moved by a stepper motor that is controlled by a microprocessor, and in a DVD player the automatic eject feature is also controlled by a microprocessor. During the manufacturing process, microprocessors automate manufacturing processes by receiving input signals from sensors and relays and sending output signals to devices such as motors, switches, and lamps. "Microprocessor-controlled" motors are controlled by sequences of high and low (on/off) signals that are delivered at specific rates, often on the order of a few milliseconds or less. The timing and number of separate high/low signals differ from one motor to the next, but they can all be controlled by microprocessors.

Working in teams of two or three, come up with situations where a control is activated to perform a function. These situations can be either manual or automatic. For example, switching on or off a light switch manually controls the light in the room. Other devices automatically control other functions in your home, automobile, or in other locations. Record as many situations as your team can think of within the time allotted. Which team came up with the most?

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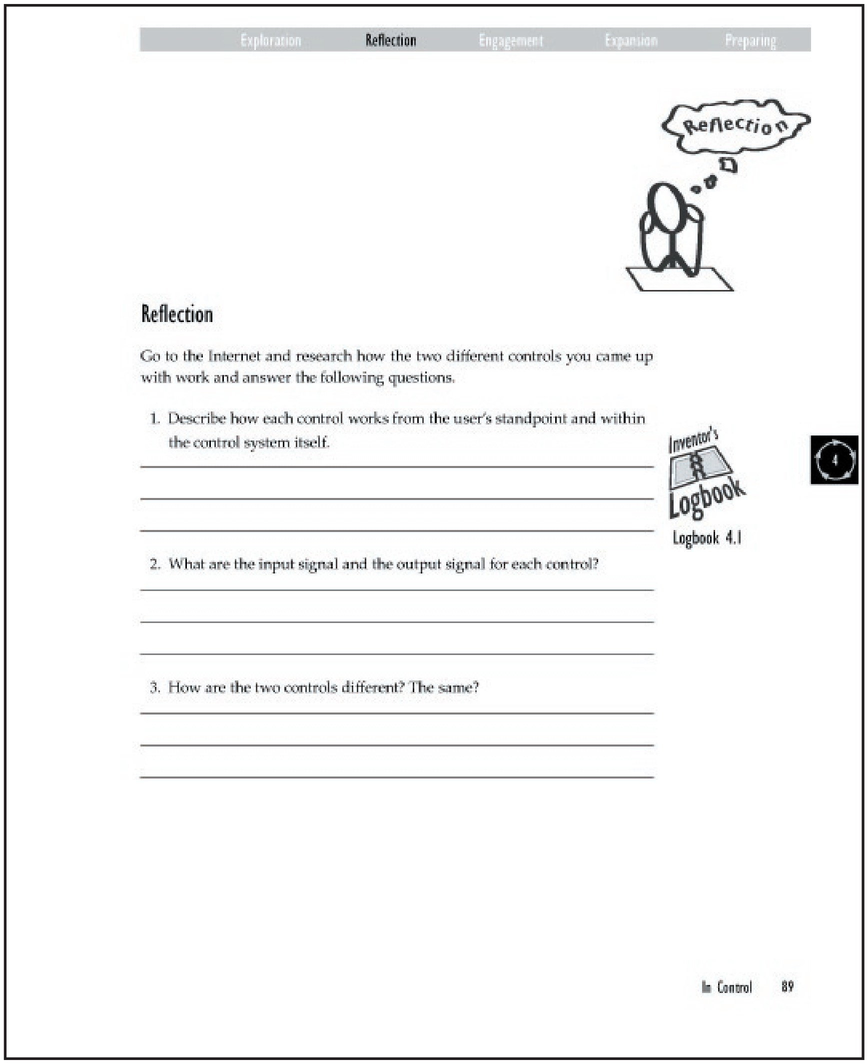
Exploration

Have students form teams of two and three to come up with examples of using controls to perform a function. Allow time for students to discuss and compare each team's responses. Some examples include flushing a toilet, cruise control in an automobile, and an elevator button.



Exploration Reflection Engagement Expansion Preparing

Reflection

Reflection

Go to the Internet and research how the two different controls you came up with work and answer the following questions.

1. Describe how each control works from the user's standpoint and within the control system itself.

2. What are the input signal and the output signal for each control?

3. How are the two controls different? The same?

Inventor's Logbook

Logbook 4.1

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Reflection

Students are then asked to independently research two different control systems and answer the following questions:

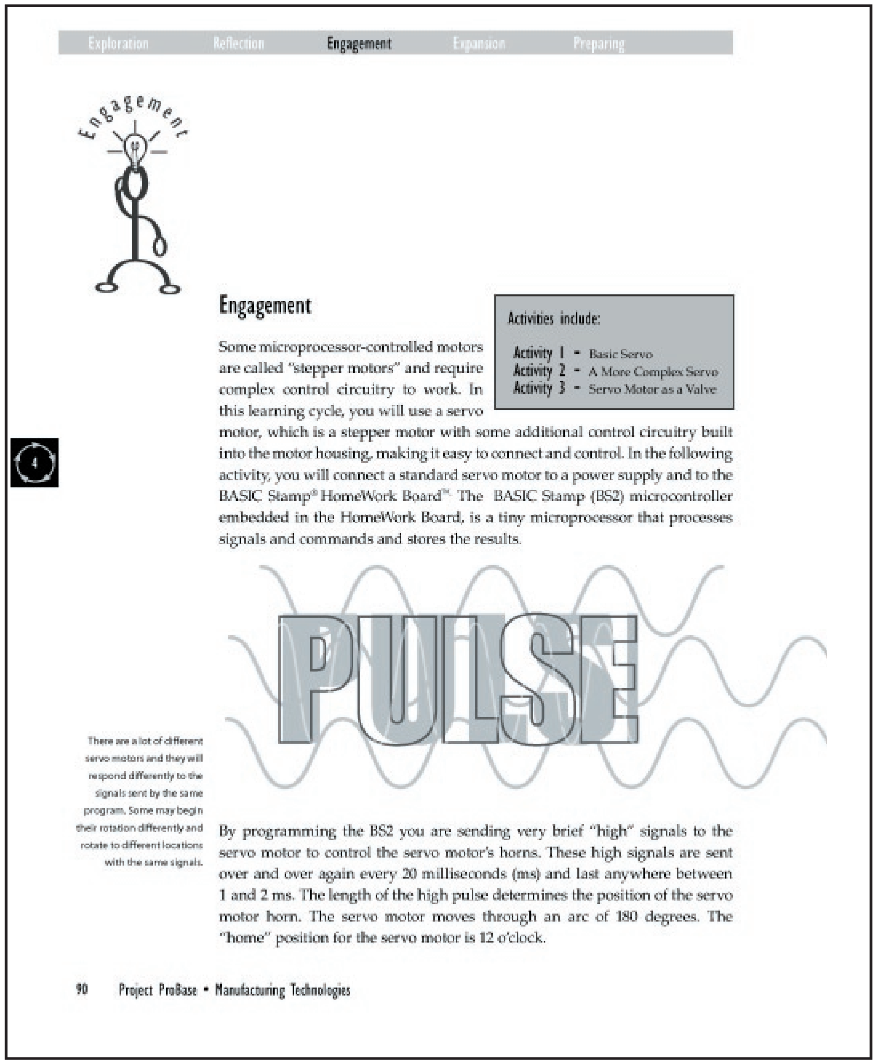
1. Describe how each control works from both the user's standpoint and within the control system itself.
   For the cruise control example, the control usually is activated by pressing a button. A light is displayed on the dash notifying the driver that the cruise control has been activated. The driver is no longer required to use the gas pedal. In many cars there is an on/off button that has to be pushed to allow the cruise control to be set. The set/accel button tells the car to maintain its current speed and the coast button decelerates the speed. The resume button will cause the car to return to the most recent speed. Hitting the brake will disengage the cruise control and cruise cannot be set below 25 mph. The cruise control system controls the speed of your car internally by adjusting the throttle position. A cruise control actuates the throttle valve by a cable connected to an actuator, instead of by pressing a pedal. The throttle valve controls the power and speed of the engine by limiting how much air the engine takes in.

2. What is the input signal and the output signal for each control?
   The input is the user's action of pressing the button, which gives the output of turning the cruise control on and displaying the light on the dash.

3. How are the two controls different? The same?
   Students should compare their answers from the two questions above for each control they chose to research.

Engagement

The BASIC Stamp microcontroller (BS2) and the servo motor are relatively simple devices. Students should follow the instructions and schematics exactly as given. There is a brief introduction to understanding schematics on page 94 in the Student's Guide, along with a chart explaining a few of the schematic symbols that will be used in this *Engagement* activity. Make sure students understand how to read a schematic before they go on. Only schematics will be given in the next learning cycle for setting up circuits.



Exploration Reflection **Engagement** Expansion Preparing

Engagement

Activities include:

Activity 1 - Basic Servo
Activity 2 - A More Complex Servo
Activity 3 - Servo Motor as a Valve

Some microprocessor-controlled motors are called "stepper motors" and require complex control circuitry to work. In this learning cycle, you will use a servo motor, which is a stepper motor with some additional control circuitry built into the motor housing, making it easy to connect and control. In the following activity, you will connect a standard servo motor to a power supply and to the BASIC Stamp® HomeWork Board™. The BASIC Stamp (BS2) microcontroller embedded in the HomeWork Board, is a tiny microprocessor that processes signals and commands and stores the results.

PULSE

There are a lot of different servo motors and they will respond differently to the signals sent by the same program. Some may begin their rotation differently and rotate to different locations with the same signals.

By programming the BS2 you are sending very brief "high" signals to the servo motor to control the servo motor's horns. These high signals are sent over and over again every 20 milliseconds (ms) and last anywhere between 1 and 2 ms. The length of the high pulse determines the position of the servo motor horn. The servo motor moves through an arc of 180 degrees. The "home" position for the servo motor is 12 o'clock.

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Exploration | Reflection | **Engagement** | Expansion | Preparing

To build the circuit you will need:

BASIC Stamp HomeWork Board	(4) Jumper wires
Standard servo motor	9V battery
BASIC Stamp serial programming cable	Access to a personal computer and the BASIC Stamp Editor version 2.1
470 Ω Resistor (yellow-violet-brown) LED	
3-pin male/male header	

4

In other words, the center of horns one and two should line up with the center of the servo motor. Each horn should be at 90°. In order to observe the movement of the servo motor horns, there are numbers printed on each. You could also mark one of the horns with a piece of tape.

Building a Servo Circuit

You are now going to build the circuit and connect it to the servo motor and a personal computer. Once each component is connected, you will need to insert a program into the BASIC Stamp Editor software, which will send commands to the servo motor telling it to move in a clockwise position. Remember, the program is essentially telling the microprocessor (the BASIC Stamp) to deliver a series of very brief "high" signals to the servo motor making it turn, in this case, to the right. You may not entirely understand the program commands, but try to observe the servo motor's motion and answer the questions that follow.

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4

Teaching Tips

Depending on students' knowledge of basic circuitry, you may need to go over some of the basics of electronics and circuitry, such as how a breadboard works and how to read a schematic. For an introduction to the BASIC Stamp HomeWork Board and a basic explanation of electronic components, see *ProBase's Introduction to Parallax's BASIC Stamp HomeWork Board.*

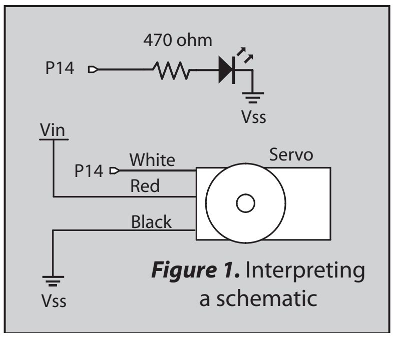


Figure 1. Interpreting a schematic

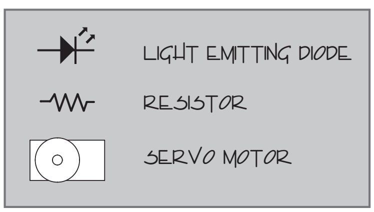
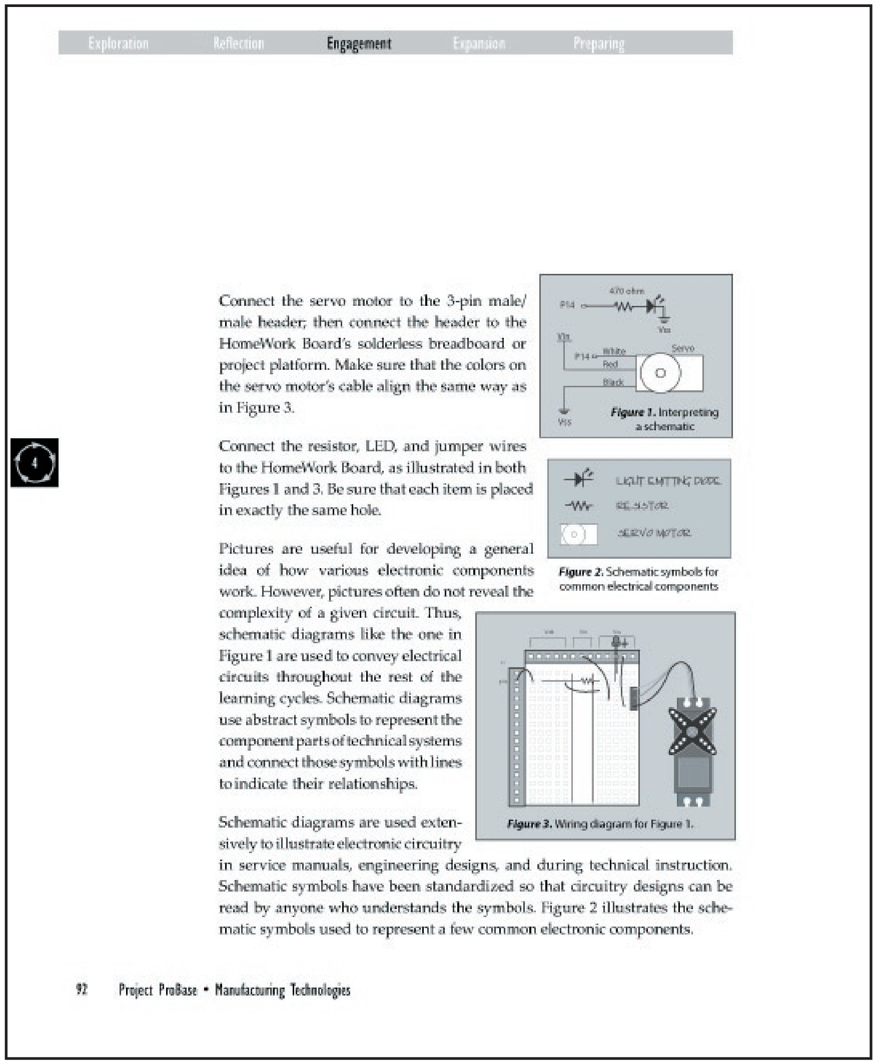


Figure 2. Schematic symbols for common electrical components


Exploration Reflection Engagement Expansion Preparing

Connect the servo motor to the 3-pin male/male header; then connect the header to the HomeWork Board's solderless breadboard or project platform. Make sure that the colors on the servo motor's cable align the same way as in Figure 3.

Connect the resistor, LED, and jumper wires to the HomeWork Board, as illustrated in both Figures 1 and 3. Be sure that each item is placed in exactly the same hole.

Pictures are useful for developing a general idea of how various electronic components work. However, pictures often do not reveal the complexity of a given circuit. Thus, schematic diagrams like the one in Figure 1 are used to convey electrical circuits throughout the rest of the learning cycles. Schematic diagrams use abstract symbols to represent the component parts of technical systems and connect those symbols with lines to indicate their relationships.

Schematic diagrams are used extensively to illustrate electronic circuitry in service manuals, engineering designs, and during technical instruction. Schematic symbols have been standardized so that circuitry designs can be read by anyone who understands the symbols. Figure 2 illustrates the schematic symbols used to represent a few common electronic components.

Figure 1. Interpreting a schematic

Figure 2. Schematic symbols for common electrical components

Figure 3. Wiring diagram for Figure 1.

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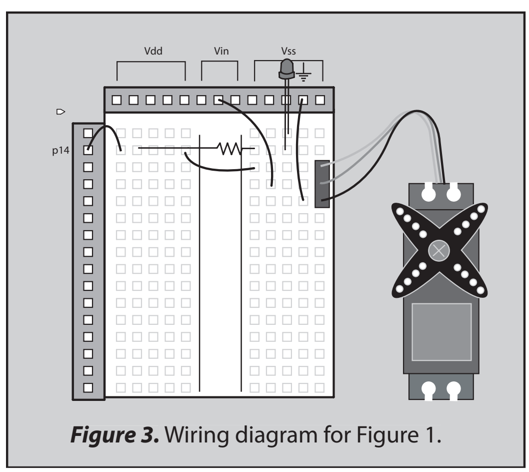
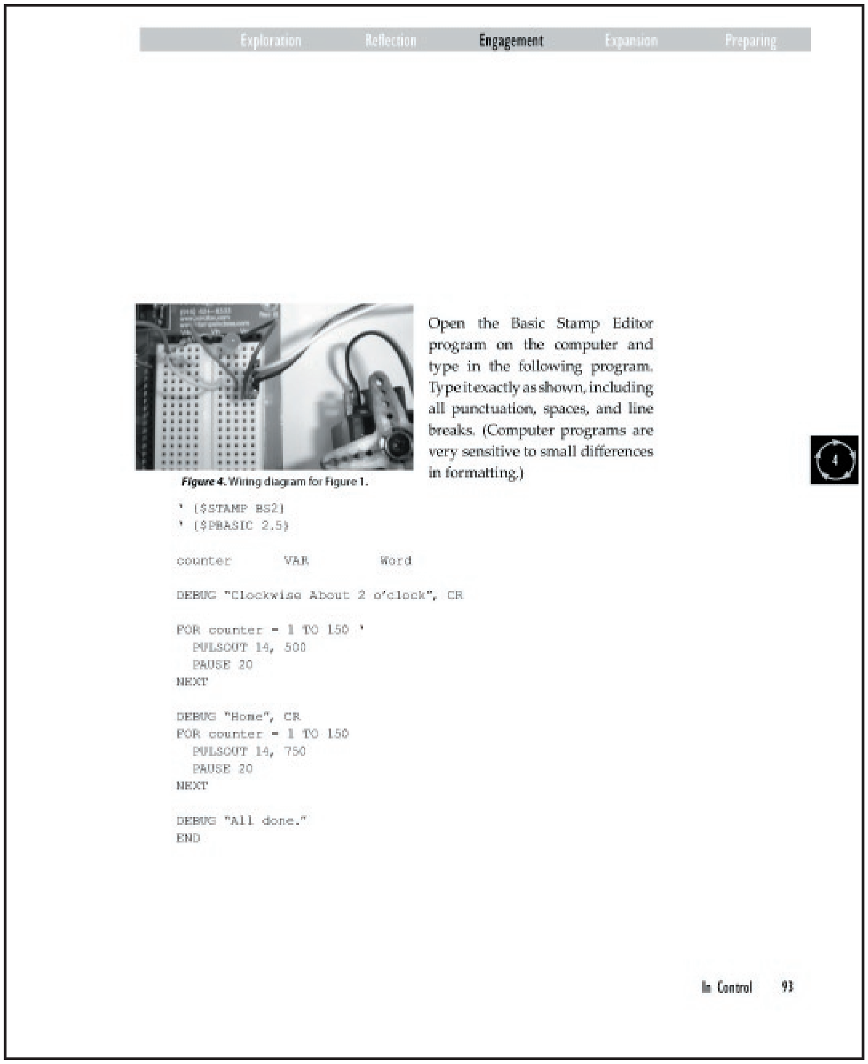


Figure 3. Wiring diagram for Figure 1.



Open the Basic Stamp Editor program on the computer and type in the following program. Type it exactly as shown, including all punctuation, spaces, and line breaks. (Computer programs are very sensitive to small differences in formatting.)

Figure 4. Wiring diagram for Figure 1.

```
' {$STAMP BS2}
' {$PBASIC 2.5}

counter      VAR        Word

DEBUG "Clockwise About 2 o'clock", CR

FOR counter = 1 TO 150 '
  PULSOUT 14, 500
  PAUSE 20
NEXT

DEBUG "Home", CR
FOR counter = 1 TO 150
  PULSOUT 14, 750
  PAUSE 20
NEXT

DEBUG "All done."
END
```

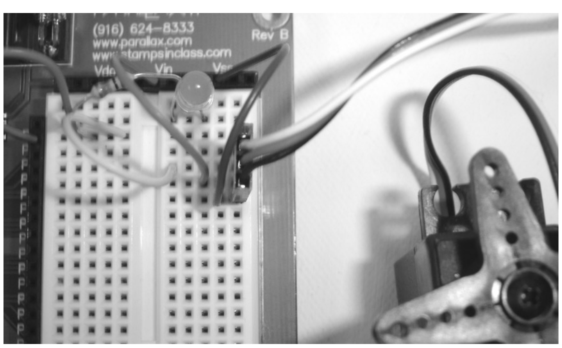
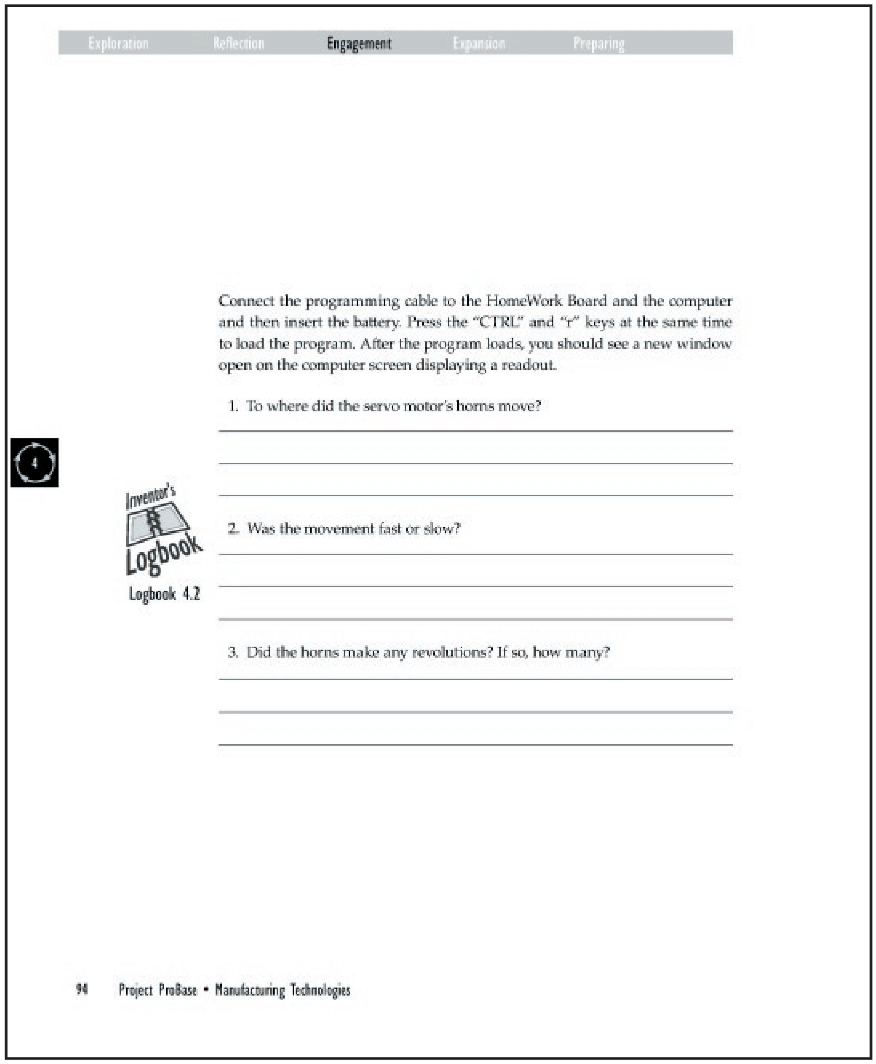



Figure 3. Wiring diagram for Figure 1.

After they have attached the servo motor and run the program, have the students address the following set of questions:

> Where did the servo's horns move to?
> *The servo's horns should move to the 2 o'clock position in a clockwise motion.*
>
> Was the movement fast or slow?
> *The servo should move relatively quickly.*
>
> Did the horns make any revolutions?
> *The servo should never make a revolution. The Parallax servo is designed to rotate through an 180° arc.*



Exploration | Reflection | Engagement | Expansion | Preparing

Connect the programming cable to the HomeWork Board and the computer and then insert the battery. Press the "CTRL" and "r" keys at the same time to load the program. After the program loads, you should see a new window open on the computer screen displaying a readout.

Inventor's Logbook

Logbook 4.2

1. To where did the servo motor's horns move?

2. Was the movement fast or slow?

3. Did the horns make any revolutions? If so, how many?

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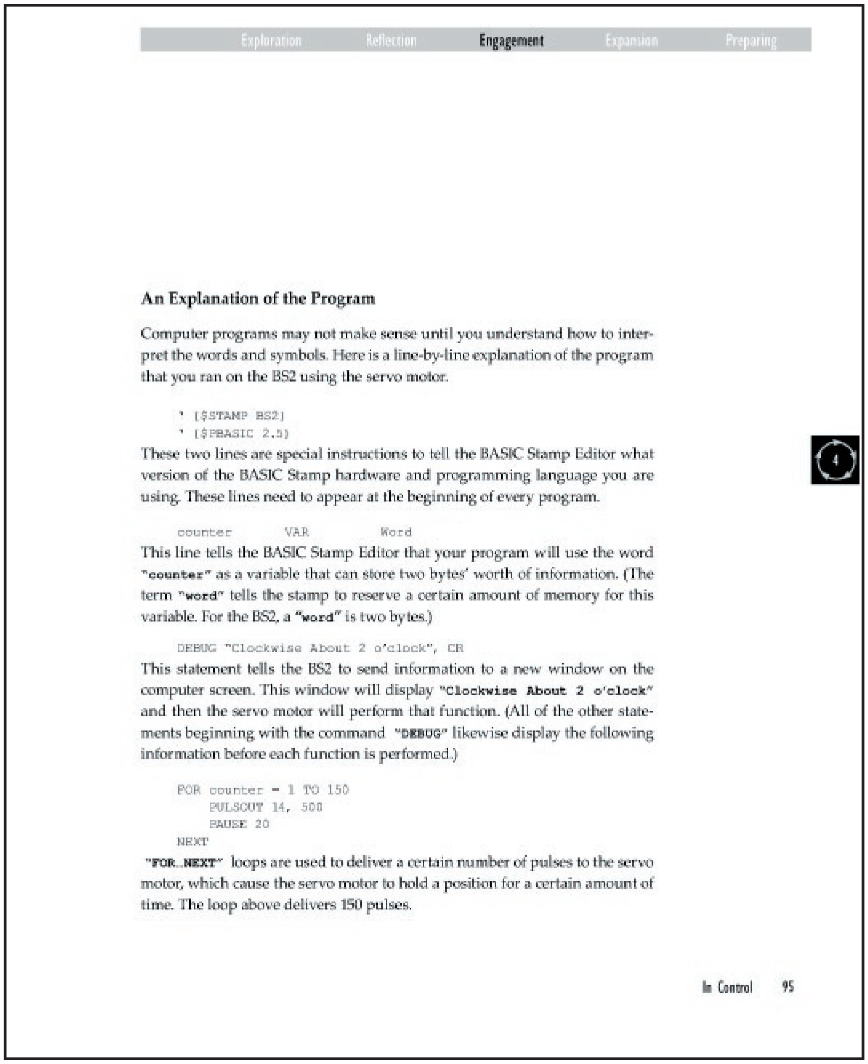


An Explanation of the Program

Computer programs may not make sense until you understand how to interpret the words and symbols. Here is a line-by-line explanation of the program that you ran on the BS2 using the servo motor.

```
' {$STAMP BS2}
' {$PBASIC 2.5}
```

These two lines are special instructions to tell the BASIC Stamp Editor what version of the BASIC Stamp hardware and programming language you are using. These lines need to appear at the beginning of every program.

```
counter     VAR      Word
```

This line tells the BASIC Stamp Editor that your program will use the word **"counter"** as a variable that can store two bytes' worth of information. (The term **"word"** tells the stamp to reserve a certain amount of memory for this variable. For the BS2, a **"word"** is two bytes.)

```
DEBUG "Clockwise About 2 o'clock", CR
```

This statement tells the BS2 to send information to a new window on the computer screen. This window will display **"Clockwise About 2 o'clock"** and then the servo motor will perform that function. (All of the other statements beginning with the command **"DEBUG"** likewise display the following information before each function is performed.)

```
FOR counter = 1 TO 150
    PULSOUT 14, 500
    PAUSE 20
NEXT
```

"FOR...NEXT" loops are used to deliver a certain number of pulses to the servo motor, which cause the servo motor to hold a position for a certain amount of time. The loop above delivers 150 pulses.

An explanation follows the questions so students will understand the program. Students are then given a chance to manipulate a few variables of the program and observe the change.

The "PULSOUT" command delivers pulses that instruct the servo motor on where to position its horns.

The first number (14) following the "PULSOUT" command is the Pin argument, which tells the BS2 which I/O pin the signal is sent on. A jumper wire, resistor, and LED are all connected in Pin 14. All are receiving signals through this Pin.

4

A millionth of a second is called a microsecond. The Greek letter µ is used in place of the word micro and the letter s is used in place of second. So instead of writing 2 microseconds, you can write 2 µs. One thousandth of a second is called a millisecond, and is abbreviated ms: 1 ms = 1,000 µs

The following number (500) is the Duration. The Duration controls where the servo motor turns to by telling the servo motor how long the signal will last. The Duration number is converted into 2-millionth-of-a-seconds (µs). So "PULSOUT 14, 500" sends 150 pulses to pin 14 that last 1,000 µs or 1ms (500 x 2 µs). Horn one will move clockwise to about the 2 o'clock position.

To calculate the duration from a given variable you can use the following equations:
To convert time from milliseconds to a Duration: Duration = number of ms x 500. To figure out the Duration of an unknown PULSOUT you can use this equation: number of ms = Duration/500ms.

```
FOR counter = 1 TO 150
  PULSOUT 14, 750
  PAUSE 20
NEXT
```

This last loop is the home position. You should always include this command as your final position so the servo motor can begin and end from home. This command tells the BS2 to deliver 150 pulses, each of which lasts 1.5 ms (750 x 2 ms = 1500 ms or 1.5.) This instructs the servo motor to go to its center (home)

4

position.

More Complexity

The next step is to send commands to the servo motor, which will change the direction the horns move. The previous program turned the servo motor's horns once in a clockwise position, lasting 1 ms. Then the program returned the horns to center or home. By adding another set of commands to the first set, the horns will move in both directions and then return home.

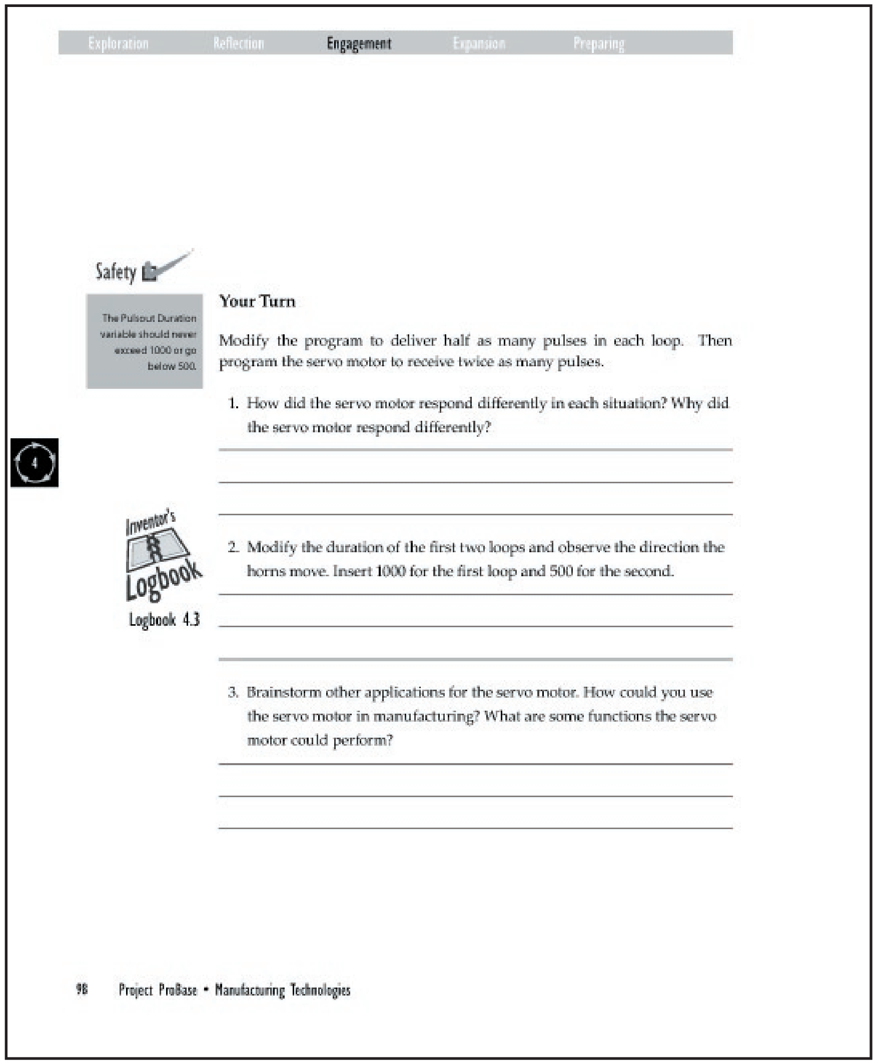
```
' {$STAMP BS2}
' {$PBASIC 2.5}

counter      VAR       Word

DEBUG "Clockwise About 2 o'clock", CR

FOR counter = 1 TO 150
  PULSOUT 14, 500
  PAUSE 20
NEXT

DEBUG "Counterclockwise About 10 o'clock", CR
FOR counter = 1 TO 150
  PULSOUT 14, 1000
  PAUSE 20
NEXT

DEBUG "Home", CR
FOR counter = 1 TO 150
  PULSOUT 14, 750
  PAUSE 20
NEXT

DEBUG "All done."
END
```

Modify the program to deliver half as many pulses in each loop. Then program the servo to receive twice as many pulses.

1. How did the servo respond differently in each situation? Why did the servo respond differently?
   Pulses cause the servo to hold a position for a certain amount of time. By changing the number, you change how long it stays in a given position.

2. Modify the duration of the first two loops and observe the direction the horns move. Insert 1000 for the first loop and 500 for the second.
   The duration controls where the servo turns to by telling the servo how long the signal will last. By changing the number, the servo will move to a different location.

Make sure to point out that the **PULSOUT** variable should never exceed 1000 or go below 500.



Exploration Reflection Engagement Expansion Preparing

Safety

The Pulsout Duration variable should never exceed 1000 or go below 500.

Inventor's Logbook

Logbook 4.3

Your Turn

Modify the program to deliver half as many pulses in each loop. Then program the servo motor to receive twice as many pulses.

1. How did the servo motor respond differently in each situation? Why did the servo motor respond differently?

2. Modify the duration of the first two loops and observe the direction the horns move. Insert 1000 for the first loop and 500 for the second.

3. Brainstorm other applications for the servo motor. How could you use the servo motor in manufacturing? What are some functions the servo motor could perform?

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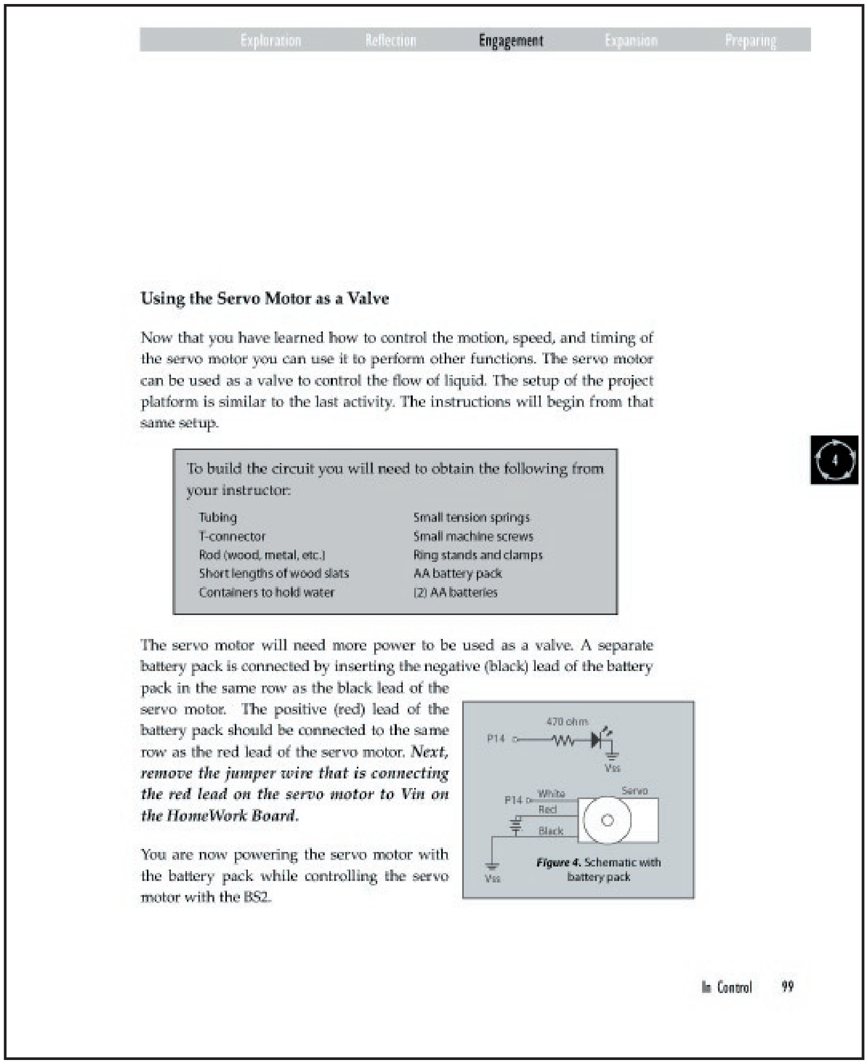
3. Brainstorm other applications for the servo motor. How could you use the servo motor in manufacturing? What are some functions the servo motor could perform?
   These questions are important in order to prepare the students to design a valve system using the servo motor later in this learning cycle. Students may also decide to use the servo motor for their Primary Challenge solution. Some examples include connecting the servo to a light switch and programming it to turn the lights on and off or connecting the servo to a faucet and programming it to turn the water on and off.



Exploration | Reflection | Engagement | Expansion | Preparing

Using the Servo Motor as a Valve

Now that you have learned how to control the motion, speed, and timing of the servo motor you can use it to perform other functions. The servo motor can be used as a valve to control the flow of liquid. The setup of the project platform is similar to the last activity. The instructions will begin from that same setup.

To build the circuit you will need to obtain the following from your instructor:

Tubing	Small tension springs
T-connector	Small machine screws
Rod (wood, metal, etc.)	Ring stands and clamps
Short lengths of wood slats	AA battery pack
Containers to hold water	(2) AA batteries

The servo motor will need more power to be used as a valve. A separate battery pack is connected by inserting the negative (black) lead of the battery pack in the same row as the black lead of the servo motor. The positive (red) lead of the battery pack should be connected to the same row as the red lead of the servo motor. ***Next, remove the jumper wire that is connecting the red lead on the servo motor to Vin on the HomeWork Board.***

You are now powering the servo motor with the battery pack while controlling the servo motor with the BS2.

Figure 4. Schematic with battery pack

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servo to move the valve rod in and out. They can construct their system however they choose, as long as it is designed to stop the flow of water. They can measure the success of their design by answering the questions that follow.

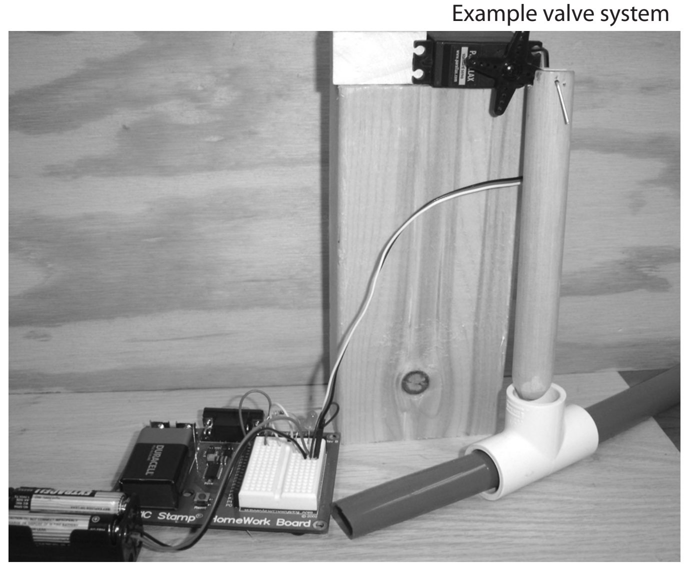
In the example pictured below, the water infeed would be connected to a plastic bottle holding water, which would provide a reservoir. A small pan or bowl would be used to collect the water as it flows through the tubing. The tubing is connected through the t-connector. The rod is set vertically in the t-connector, and with a simple mechanical linkage the servo can be programmed to raise and lower the rod, creating a valve system. This is one of many potential solutions to the design problem.

Servo Motor as a Valve

Students are asked to apply the programming knowledge they have learned and create a valve system using the servo motor. Using the servo as a valve will help students prepare for their *Primary Challenge* solution.

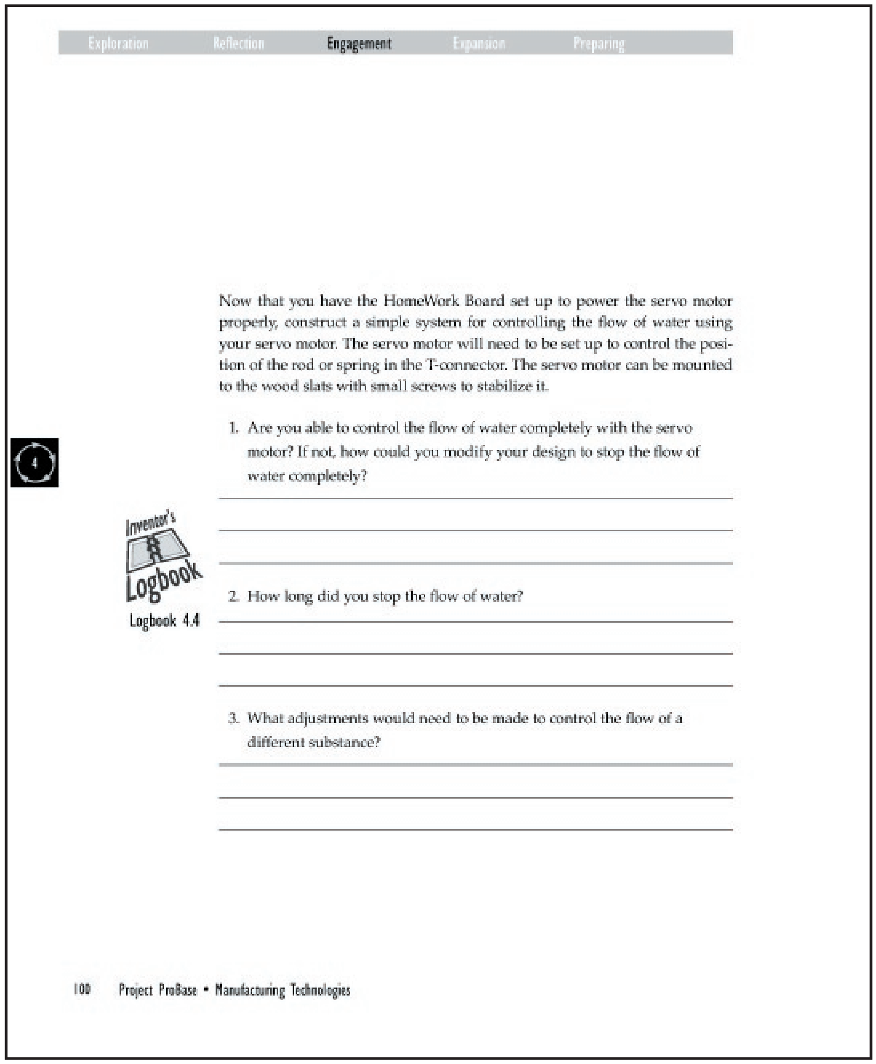
Instructions are given to connect a separate battery pack to the HomeWork Board, but students are given little guidance in the implementation of their valve system. From the materials they are given, students will need to construct a system using the

Example valve system



You might want to provide a variety of materials for the students to choose from for each aspect of their valve system. There are different t-connecters available that can be used; you might want to purchase different ones and have students choose. Their choice will dictate the size of rod to be used. The material to be used for their rod is also a decision they can make.

The type of tubing needs to be flexible because the servo does not generate a lot of force and the program students are using (the same as in the above activity) sets the servo to a specific position but does not hold it there for long. The mechanical resistance with the servo provides some tensional resistance, but if the internal friction is not sufficient, the students will need to use a tensioning spring, or some other method to hold the servo in position.



Exploration Reflection Engagement Expansion Preparing

Now that you have the HomeWork Board set up to power the servo motor properly, construct a simple system for controlling the flow of water using your servo motor. The servo motor will need to be set up to control the position of the rod or spring in the T-connector. The servo motor can be mounted to the wood slats with small screws to stabilize it.

Inventor's Logbook

Logbook 4.4

1. Are you able to control the flow of water completely with the servo motor? If not, how could you modify your design to stop the flow of water completely?
2. How long did you stop the flow of water?
3. What adjustments would need to be made to control the flow of a different substance?

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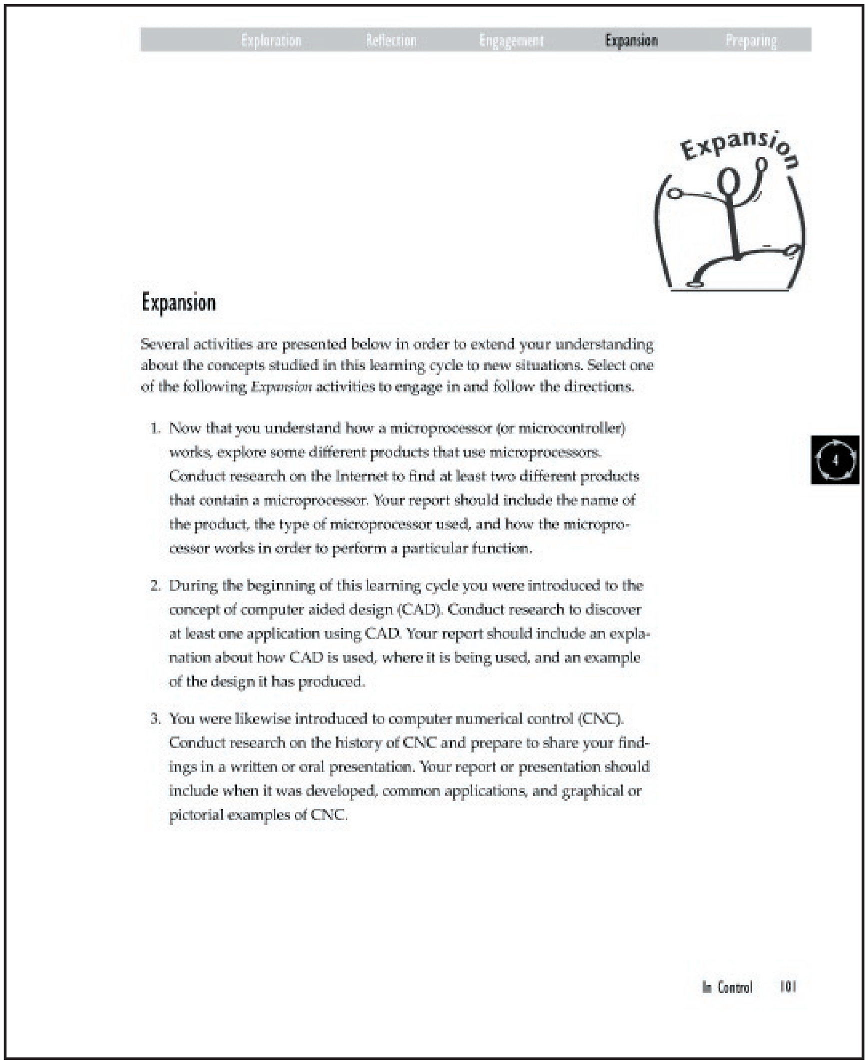
Have the students experiment with this and then answer the questions that follow:

1. Are you able to control the flow of water completely with the servo? If not, how could you modify your design to stop the flow of water completely?
2. How long did you stop the flow of water?
3. What adjustments would need to be made to control the flow of a different substance?



Expansion

Expansion

Several activities are presented below in order to extend your understanding about the concepts studied in this learning cycle to new situations. Select one of the following *Expansion* activities to engage in and follow the directions.

1. Now that you understand how a microprocessor (or microcontroller) works, explore some different products that use microprocessors. Conduct research on the Internet to find at least two different products that contain a microprocessor. Your report should include the name of the product, the type of microprocessor used, and how the microprocessor works in order to perform a particular function.
2. During the beginning of this learning cycle you were introduced to the concept of computer aided design (CAD). Conduct research to discover at least one application using CAD. Your report should include an explanation about how CAD is used, where it is being used, and an example of the design it has produced.
3. You were likewise introduced to computer numerical control (CNC). Conduct research on the history of CNC and prepare to share your findings in a written or oral presentation. Your report or presentation should include when it was developed, common applications, and graphical or pictorial examples of CNC.

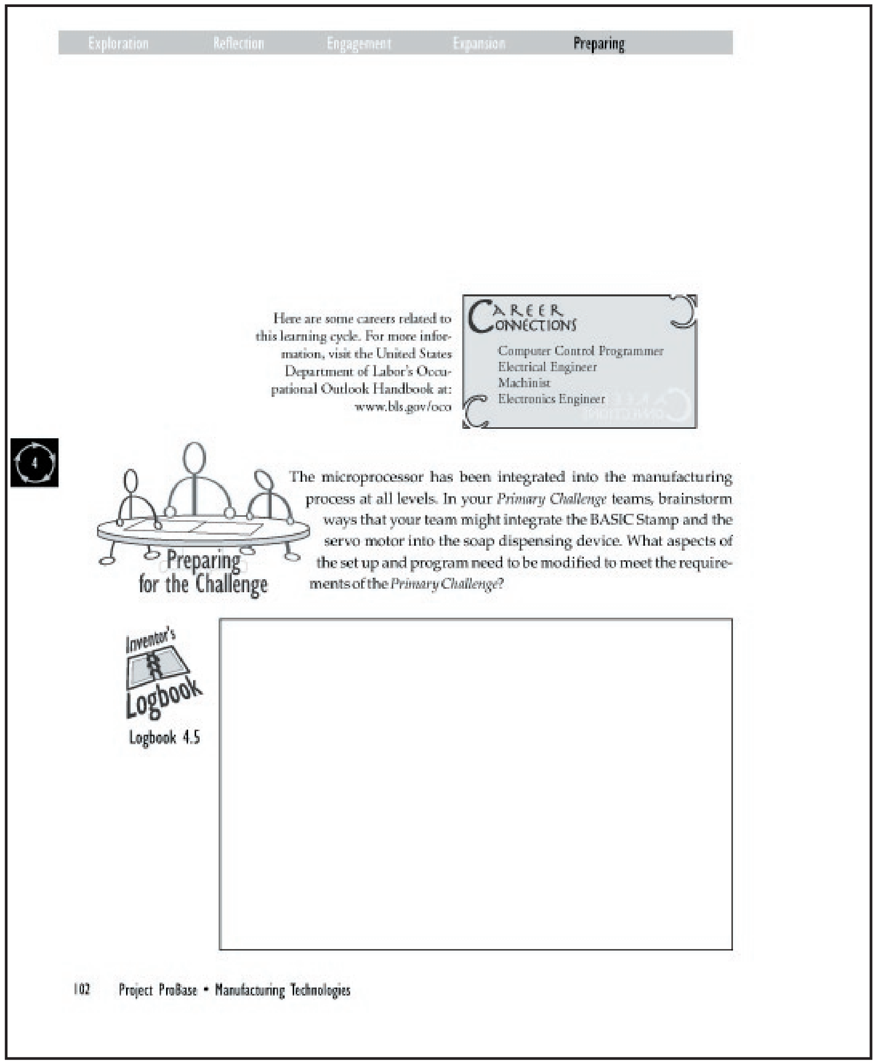
Expansion

Although not required, these *Expansion* activities are designed to cause teams to delve deeper into the concepts explored in the learning cycle.

Students are asked to research one of three different topics: products that contain microprocessors, computer aided design, and computer numerical control. They must also prepare a report to explain their findings.

Preparing for the Challenge

After students complete the *Expansion* activity, ask them to meet in their *Primary Challenge* teams so they can brainstorm together ways to integrate the BASIC Stamp and servo motor into their soap dispensing device. Students should think through the necessary steps and modifications in order to include the servo into their device.



Exploration Reflection Engagement Expansion **Preparing**

Here are some careers related to this learning cycle. For more information, visit the United States Department of Labor's Occupational Outlook Handbook at: www.bls.gov/oco

CAREER CONNECTIONS

Computer Control Programmer
Electrical Engineer
Machinist
Electronics Engineer

Preparing for the Challenge

The microprocessor has been integrated into the manufacturing process at all levels. In your *Primary Challenge* teams, brainstorm ways that your team might integrate the BASIC Stamp and the servo motor into the soap dispensing device. What aspects of the set up and program need to be modified to meet the requirements of the *Primary Challenge*?

Inventor's Logbook

Logbook 4.5

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Student Assessment

An assessment rubric has been developed for the *Exploration* and *Engagement* activities. Feel free to change this rubric to better suit your particular needs.

In Control

Element	Criteria				Points
	4	3	2	1	
Engagement: Controlling a Servo Motor	Successfully connected the servo to the Basic Stamp; thoroughly answered questions and completed exercises.	Successfully connected the servo to the Basic Stamp; answered and completed most of the exercises.	Encountered difficulty in connecting the servo to the Basic Stamp; answered and completed a few of the exercises.	Did not successfully connect the servo to the Basic Stamp; could not answer and complete the exercises.	
Expansion: Servo as a Valve	Successfully created a valve system using the servo; applied system to the *Primary Challenge.*	Successfully created a valve system; difficulty brainstorming application of servo to *Primary Challenge.*	Encountered difficulty creating a valve system; unable to brainstorm for *Primary Challenge.*	Did not successfully create a valve system; did not brainstorm for *Primary Challenge.*	
Inventor's Logbook Entries	Fully answered all entries and provided good examples.	Answered most of the entries and provided some examples.	Answered few entries and provided few examples.	Did not answer entries and did not provide examples.	
				Total	

4

Learning Cycle Five

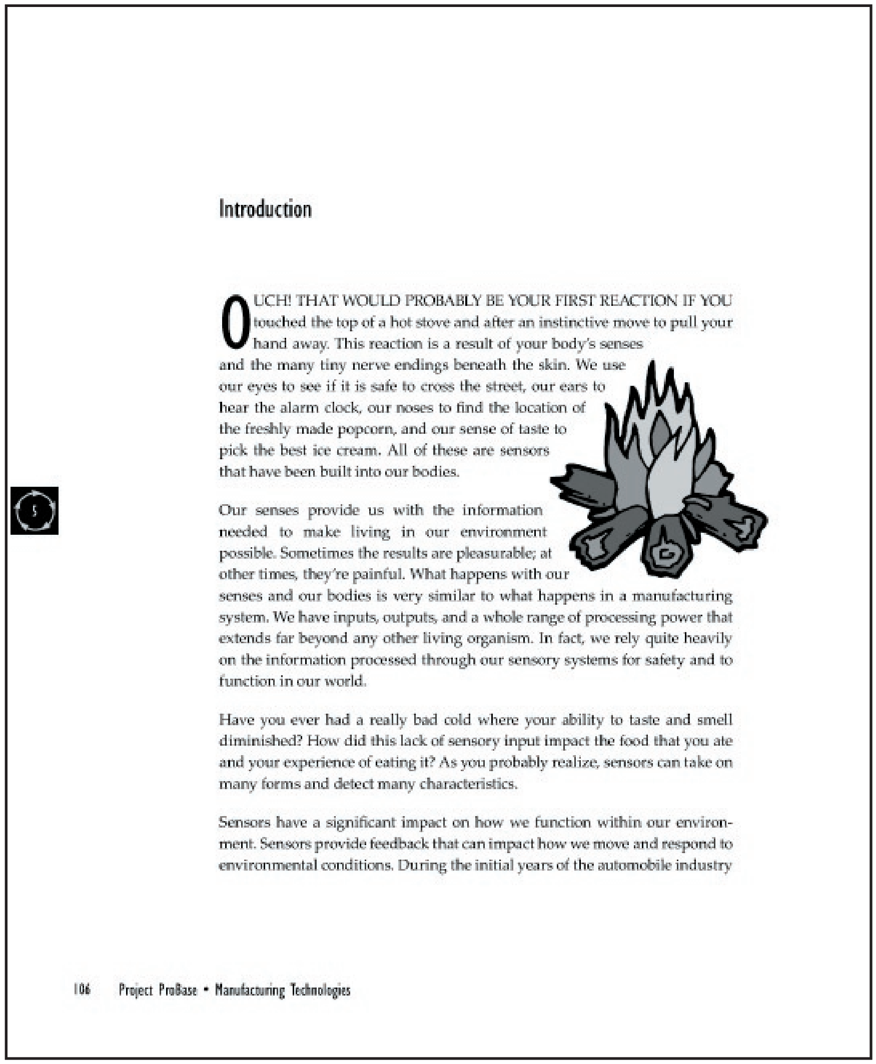
Making Sense of it All

5

Making Sense of it All

Introduction

This learning cycle provides opportunities for students to interact with different types of sensors and learn about their functions within the manufacturing process. They will get a chance to solve a manufacturing problem using their choice of sensor and build upon their knowledge from the previous learning cycle using the BASIC Stamp.



Introduction

OUCH! THAT WOULD PROBABLY BE YOUR FIRST REACTION IF YOU touched the top of a hot stove and after an instinctive move to pull your hand away. This reaction is a result of your body's senses and the many tiny nerve endings beneath the skin. We use our eyes to see if it is safe to cross the street, our ears to hear the alarm clock, our noses to find the location of the freshly made popcorn, and our sense of taste to pick the best ice cream. All of these are sensors that have been built into our bodies.

Our senses provide us with the information needed to make living in our environment possible. Sometimes the results are pleasurable; at other times, they're painful. What happens with our senses and our bodies is very similar to what happens in a manufacturing system. We have inputs, outputs, and a whole range of processing power that extends far beyond any other living organism. In fact, we rely quite heavily on the information processed through our sensory systems for safety and to function in our world.

Have you ever had a really bad cold where your ability to taste and smell diminished? How did this lack of sensory input impact the food that you ate and your experience of eating it? As you probably realize, sensors can take on many forms and detect many characteristics.

Sensors have a significant impact on how we function within our environment. Sensors provide feedback that can impact how we move and respond to environmental conditions. During the initial years of the automobile industry

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Objectives and Essential Questions

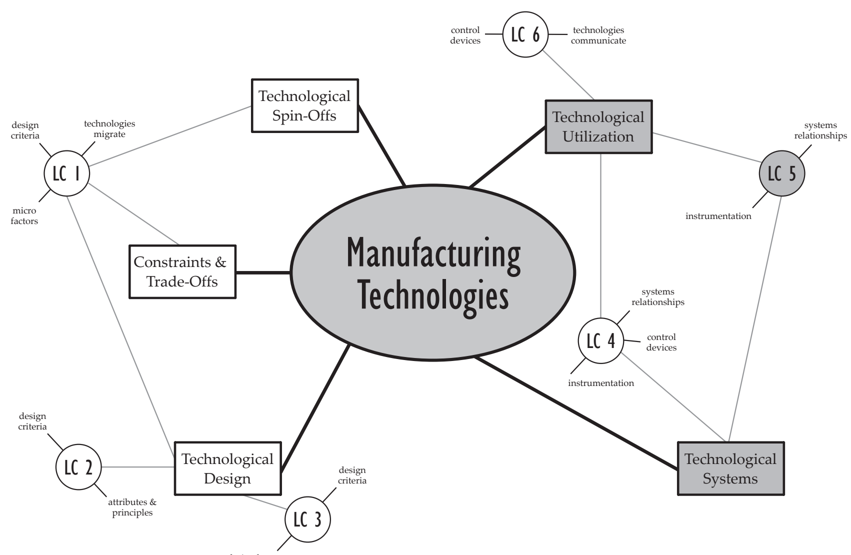
1. Explain how sensors work and how they are used in manufacturing to control technological systems and devices.

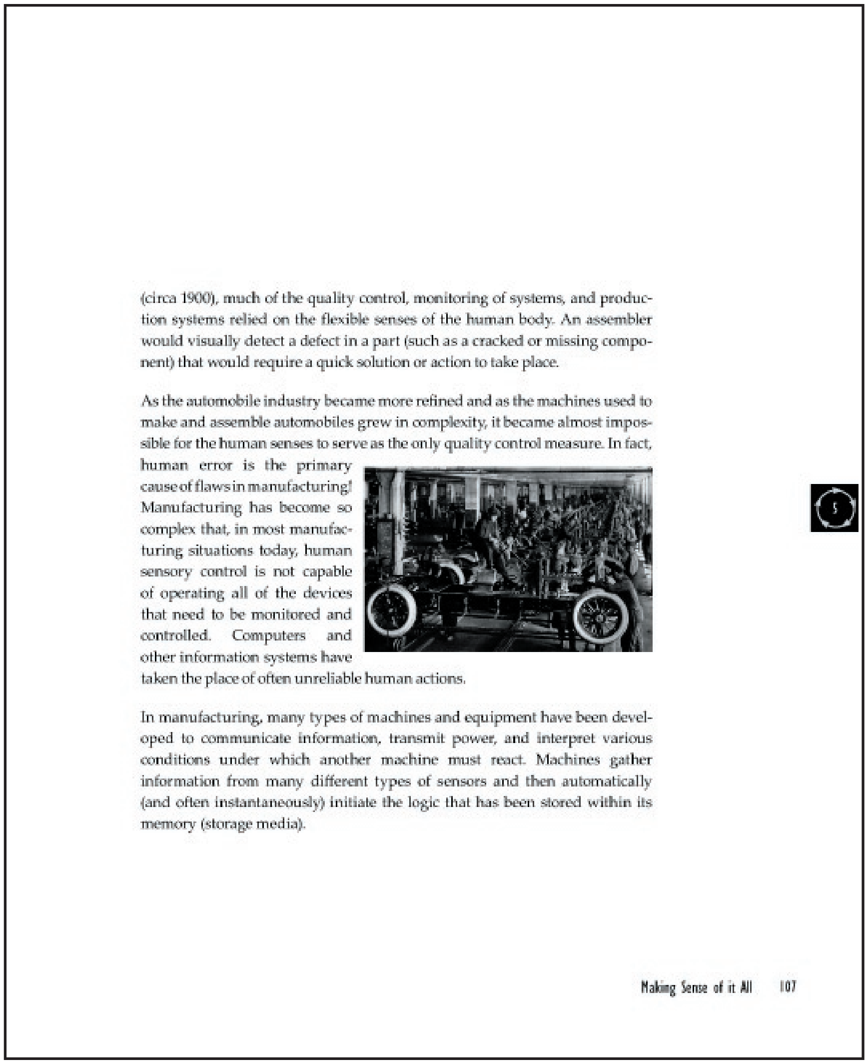
   Essential Question: What are the key elements of the various technological systems and what are the relationships between these systems?

2. Develop a program to logically control a set of inputs to achieve a desired output.

   Essential Question: How is technological instrumentation used to measure, calculate, manipulate, and predict the actions of technological devices and systems?

Manufacturing Technologies
Learning Cycle Five Concept Map





(circa 1900), much of the quality control, monitoring of systems, and production systems relied on the flexible senses of the human body. An assembler would visually detect a defect in a part (such as a cracked or missing component) that would require a quick solution or action to take place.

As the automobile industry became more refined and as the machines used to make and assemble automobiles grew in complexity, it became almost impossible for the human senses to serve as the only quality control measure. In fact, human error is the primary cause of flaws in manufacturing! Manufacturing has become so complex that, in most manufacturing situations today, human sensory control is not capable of operating all of the devices that need to be monitored and controlled. Computers and other information systems have taken the place of often unreliable human actions.

In manufacturing, many types of machines and equipment have been developed to communicate information, transmit power, and interpret various conditions under which another machine must react. Machines gather information from many different types of sensors and then automatically (and often instantaneously) initiate the logic that has been stored within its memory (storage media).

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Facility Requirements

No special facilities are required for this learning cycle. Students should have an adequate work area for assembling the electrical circuits.

Equipment and Materials

For 4 teams of 7:

(1) Each of the following sensors:
Inductive Proximity Sensor
Float Switch
Contact Sensor
Foot Switch

(4) LEDs

(4) 4 AA battery pack

(4) Alligator clips and wire

(4) 220 Ω Resistor - Students may choose to use a 220 Ω Resistor (You may want to purchase two of each sensor to have smaller teams.)

5

For 7 teams of 3 or 4:

(7) BASIC Stamp HomeWork Boards

(7) BASIC Stamp serial programming cables

(14) Contact (push-button) sensor

(7) 470 Ω Resistors

(14) 220 Ω Resistors

(14) 10K Ω Resistors

(7) LEDs

Jumper wires

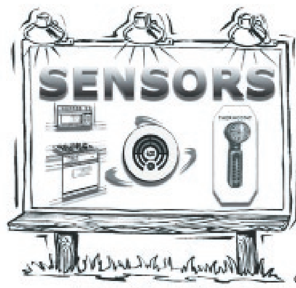
(7) 4 AA battery packs

(7) 9V battery

Estimated number of 50-minute class periods: **4**

Suggested Daily Outline

Day One	Day Two
Exploration I, Reflection I	*Exploration II, Reflection II*
Day Three	**Day Four**
Engagement	*Engagement, Preparing for the Challenge*



Information-gathering technologies, such as sensors, are much more commonly used than you may think. For example, your home probably contains dozens, if not hundreds, of components and technologies that could be classified as sensors. Examples found in most homes include heat sensors in ovens and stoves, motion detectors in security systems or outside lights, the thermostat that controls the heating and cooling systems, and the float sensor inside an automatic ice maker that closes the water valve when the ice molds are full.

Most sensors are relatively simple devices, yet when combined with machines, other sensory equipment, and networked with a primary processing system, sensors can accomplish some amazing tasks. In this learning cycle, you will explore and learn how to use different types of sensors.

Objectives

After completing this learning cycle, you will be able to:

1. Explain how sensors work and how they are used in manufacturing to control technological systems and devices.
2. Develop a program to logically control a set of inputs to achieve a desired output.

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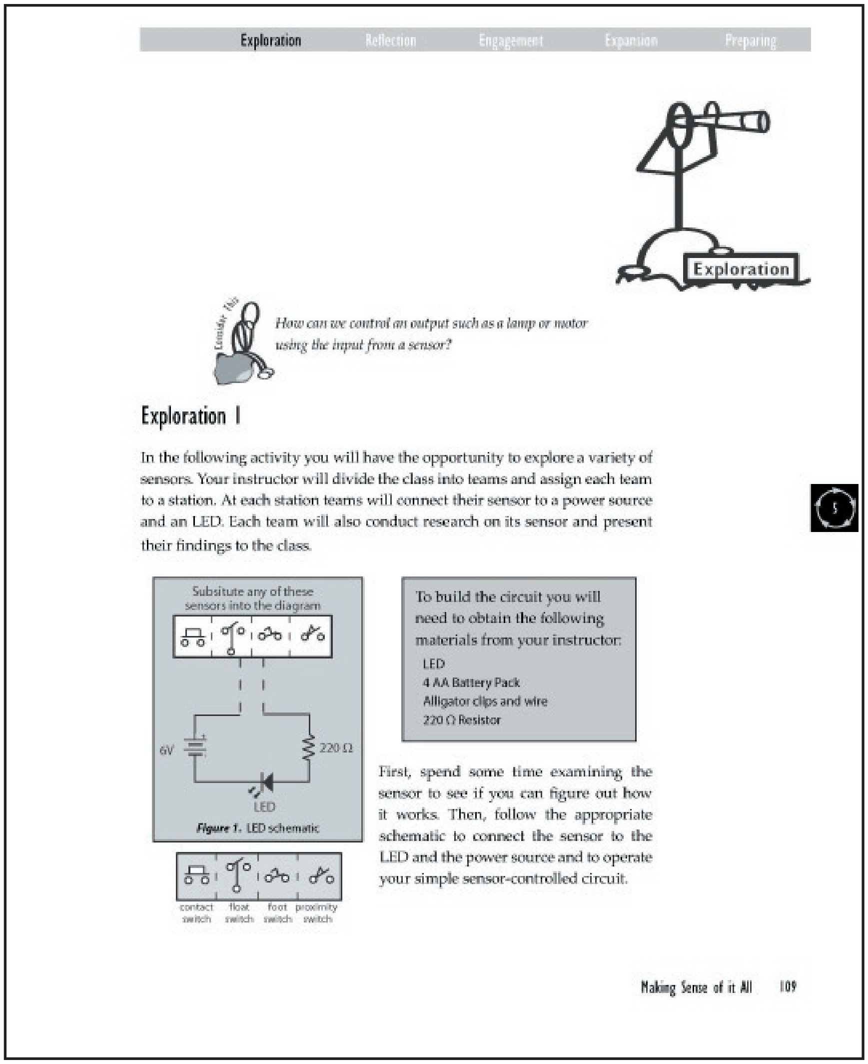

Exploration Reflection Engagement Expansion Preparing

How can we control an output such as a lamp or motor using the input from a sensor?

Exploration I

In the following activity you will have the opportunity to explore a variety of sensors. Your instructor will divide the class into teams and assign each team to a station. At each station teams will connect their sensor to a power source and an LED. Each team will also conduct research on its sensor and present their findings to the class.

Figure 1. LED schematic

To build the circuit you will need to obtain the following materials from your instructor:

LED
4 AA Battery Pack
Alligator clips and wire
220 Ω Resistor

First, spend some time examining the sensor to see if you can figure out how it works. Then, follow the appropriate schematic to connect the sensor to the LED and the power source and to operate your simple sensor-controlled circuit.

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If you decide to purchase more than one of each type of sensor, you can have more stations and more teams. You will need one sensor for each team.

Students are first asked to explore how their sensors work and then they are asked to connect the sensor to a power source and an LED by following the appropriate schematic.

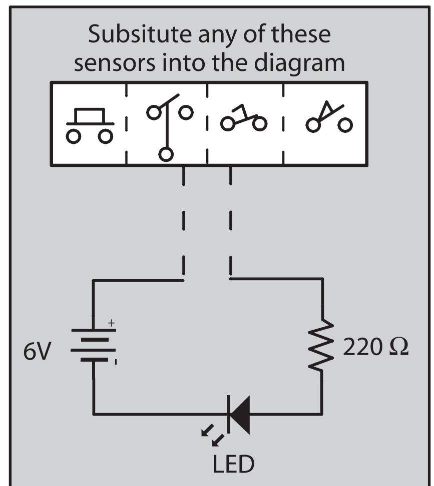
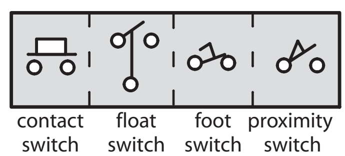


Figure 1. LED



Exploration

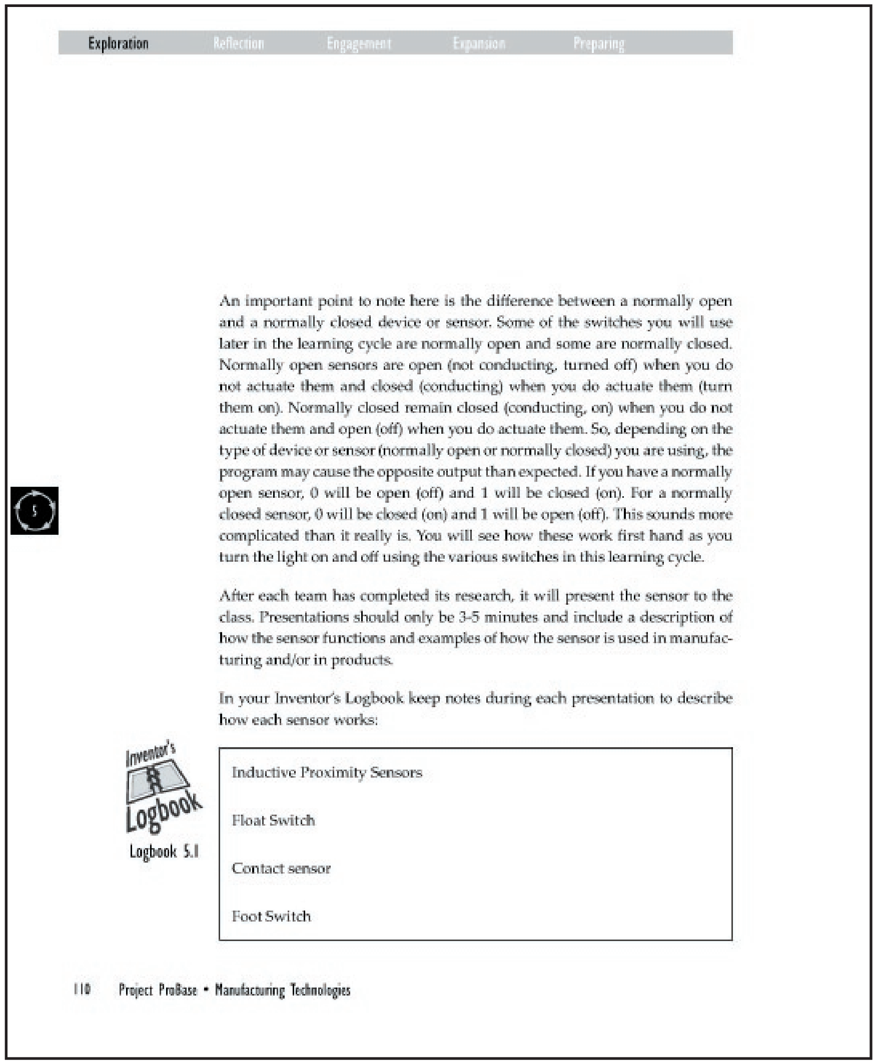
Four stations should be set up around the room with one of the four sensors at each and the following materials:

(1) LED
(1) AA battery pack
(1-3) Alligator clips and wire
(1) 220 Ω Resistor

It is important to point out here the difference between a normally-open and a normally-closed device or sensor. Some of the switches the students will use are normally open and some are normally closed. Students should understand what this means.

Normally-open sensors are open (not conducting, off) when you do not activate them and closed (conducting) when you do activate them (turn them on). Normally-closed sensors remain closed (conducting; on) when you do not activate them and open (off) when you do activate them. So, depending on the type of device or sensor (normally open or normally closed) you are using, the program may cause the opposite output than expected. If you have a normally-open sensor, 0 will be open (off) and 1 will be closed (on). For a normally-closed sensor, 0 will be closed (on) and 1 will be open (off).

Once each team has connected the sensor to the battery pack and the LED, allow time for each team to conduct research about their sensor. They should present their findings to the class. Presentations should only be 3-5 minutes and include a description of how the sensor functions and how it is used in manufacturing and/or in products.



Exploration Reflection Engagement Expansion Preparing

An important point to note here is the difference between a normally open and a normally closed device or sensor. Some of the switches you will use later in the learning cycle are normally open and some are normally closed. Normally open sensors are open (not conducting, turned off) when you do not actuate them and closed (conducting) when you do actuate them (turn them on). Normally closed remain closed (conducting, on) when you do not actuate them and open (off) when you do actuate them. So, depending on the type of device or sensor (normally open or normally closed) you are using, the program may cause the opposite output than expected. If you have a normally open sensor, 0 will be open (off) and 1 will be closed (on). For a normally closed sensor, 0 will be closed (on) and 1 will be open (off). This sounds more complicated than it really is. You will see how these work first hand as you turn the light on and off using the various switches in this learning cycle.

After each team has completed its research, it will present the sensor to the class. Presentations should only be 3-5 minutes and include a description of how the sensor functions and examples of how the sensor is used in manufacturing and/or in products.

In your Inventor's Logbook keep notes during each presentation to describe how each sensor works:

Inventor's Logbook

Logbook 5.1

Inductive Proximity Sensors
Float Switch
Contact sensor
Foot Switch

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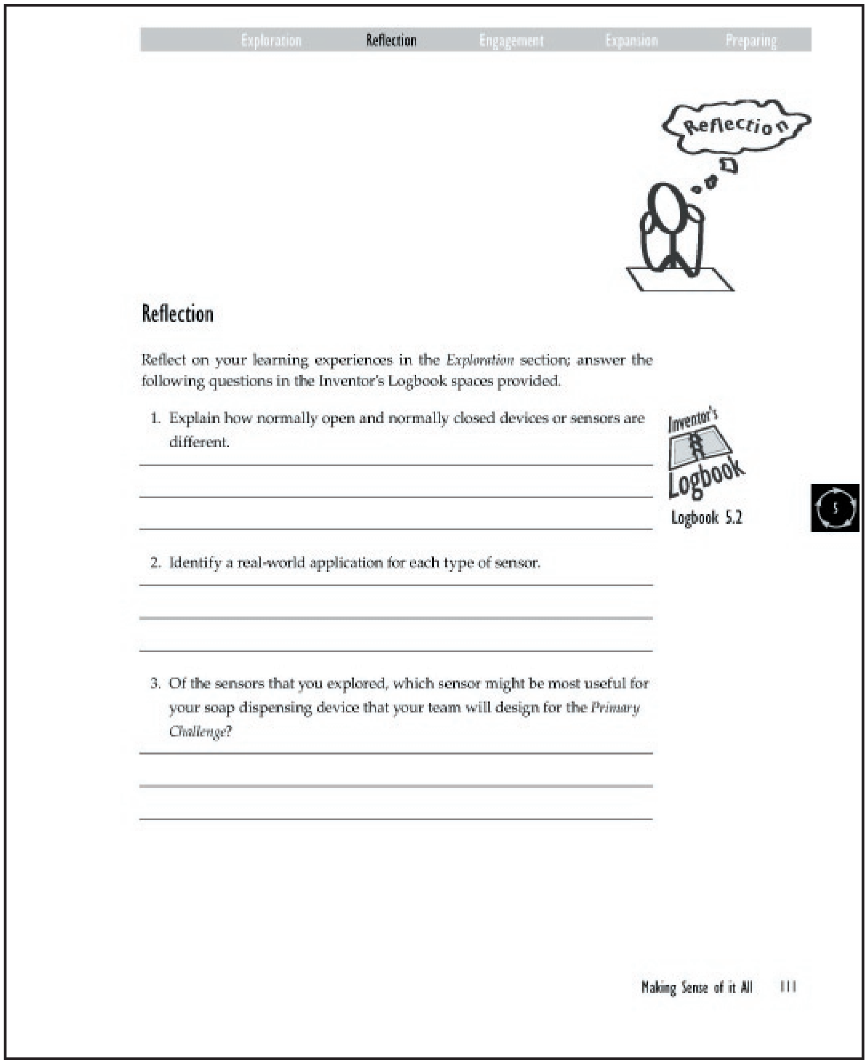
The goal for this *Exploration* is to have students realize that all sensors control circuits either by inducing a current or stopping the current flow. The LED lights up when the sensor is activated if it is a normally-open sensor because it is closing the circuit. The LED lights up when the sensor is not activated if it is a normally-closed sensor because the circuit is already closed. The inductive proximity sensor, for example, has alternating magnetic flux lines moving back and forth through a coil. As soon as the switch closes, the electrical path through the coil is complete and current is induced in the coil.

The other students should keep notes about each sensor in their Inventor's Logbook. These notes will help them decide which sensor they will use for their *Primary Challenge* solution.


Exploration Reflection Engagement Expansion Preparing

Reflection

Reflection

Reflect on your learning experiences in the *Exploration* section; answer the following questions in the Inventor's Logbook spaces provided.

1. Explain how normally open and normally closed devices or sensors are different.

Inventor's Logbook
Logbook 5.2

2. Identify a real-world application for each type of sensor.

3. Of the sensors that you explored, which sensor might be most useful for your soap dispensing device that your team will design for the *Primary Challenge*?

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Reflection

The students will be responding to the following questions in the Inventor's Logbook spaces provided in their text.

1. Explain how normally open and normally closed devices are different.
   Normally-open devices are open when you do not activate them and normally-closed are closed when you do not activate them.

2. Identify a real-world application for each type of sensor.

- *Inductive Proximity Sensors. Inductive proximity sensors are used to detect ferrous metals. They are used in food manufacturing facilities to detect foil packs inside cardboard boxes. They can be used to control machine tools and conveyor systems.*

- *Float Switch. Float switches are used to detect the level of fluids. They are used in applications where the level of a fluid needs to be monitored, such as pharmaceutical, biotech, and chemical industries as well as water tanks in factories and beverage manufacturing facilities.*

- *Contact Sensor. Contact sensors are fairly common and require physical contact with an object to work. They are used in applications where physical contact can be made, such as safety switches, machine tool brakes, and start/stop stations.*

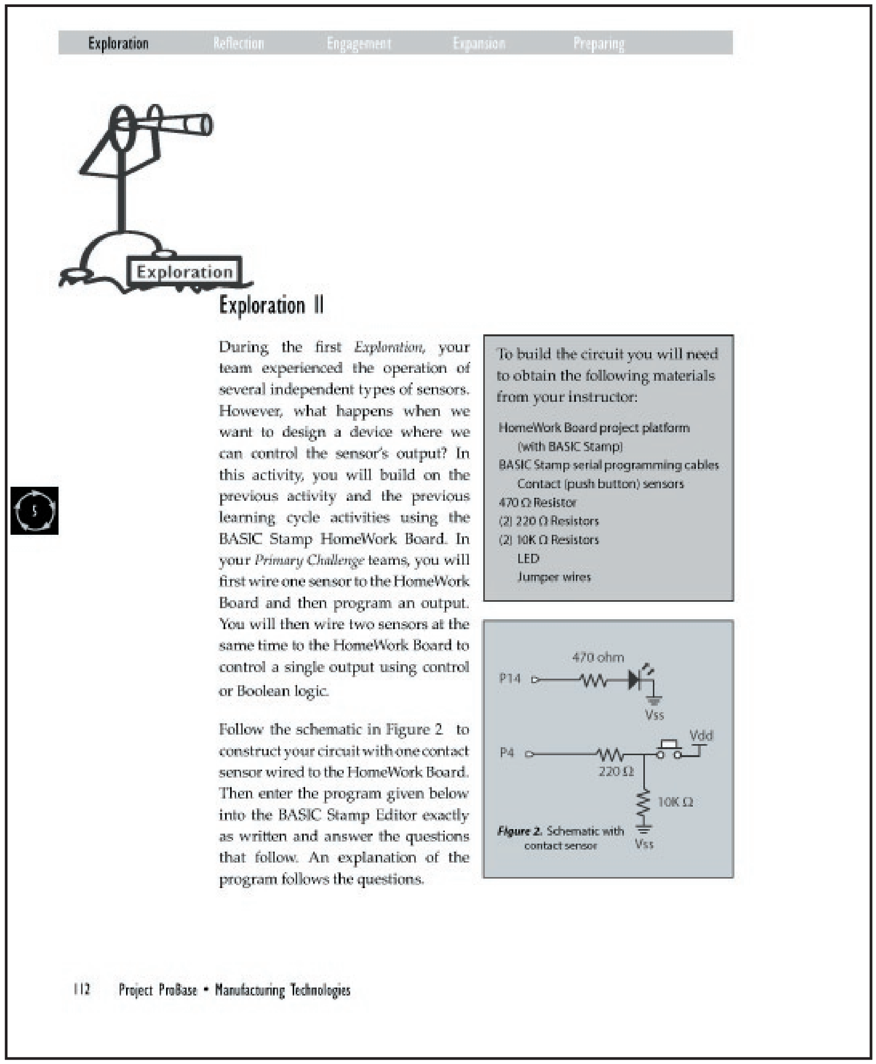
- *Foot Switch. The foot switch is a type of contact sensor. It is used when an operator needs to have both hands free from a moving part such as shear blades, or when the operator needs to have both hands available to hold things. For example, as materials are being packaged, it is sometimes necessary to have the operator hold the bag open and in the correct place.*

3. Of the sensors that you explored, which sensors might be most useful for your soap dispensing device that your team will design for the *Primary Challenge*?
Students may find ways to use almost any of these sensors in the solution to the Primary Challenge. Contact sensors can be used to detect when the soap container is positioned correctly. The proximity and photoelectric sensor can be used for this purpose also. They may create solutions where the operator can use the foot switch to control the circuit. The float switch might be used by some teams to indicate the level of liquid soap in the soap storage containers in the system.

5

Teaching Tips

You may provide students with a resistor color code chart. There is one available in *ProBase's Introduction to Parallax's BASIC Stamp HomeWork Board*.



Exploration Reflection Engagement Expansion Preparing

Exploration

Exploration II

During the first *Exploration*, your team experienced the operation of several independent types of sensors. However, what happens when we want to design a device where we can control the sensor's output? In this activity, you will build on the previous activity and the previous learning cycle activities using the BASIC Stamp HomeWork Board. In your *Primary Challenge* teams, you will first wire one sensor to the HomeWork Board and then program an output. You will then wire two sensors at the same time to the HomeWork Board to control a single output using control or Boolean logic.

Follow the schematic in Figure 2 to construct your circuit with one contact sensor wired to the HomeWork Board. Then enter the program given below into the BASIC Stamp Editor exactly as written and answer the questions that follow. An explanation of the program follows the questions.

To build the circuit you will need to obtain the following materials from your instructor:

HomeWork Board project platform
(with BASIC Stamp)
BASIC Stamp serial programming cables
Contact (push button) sensors
470 Ω Resistor
(2) 220 Ω Resistors
(2) 10K Ω Resistors
LED
Jumper wires

470 ohm
P14
Vss
Vdd
P4
220 Ω
10K Ω
Vss

Figure 2. Schematic with contact sensor

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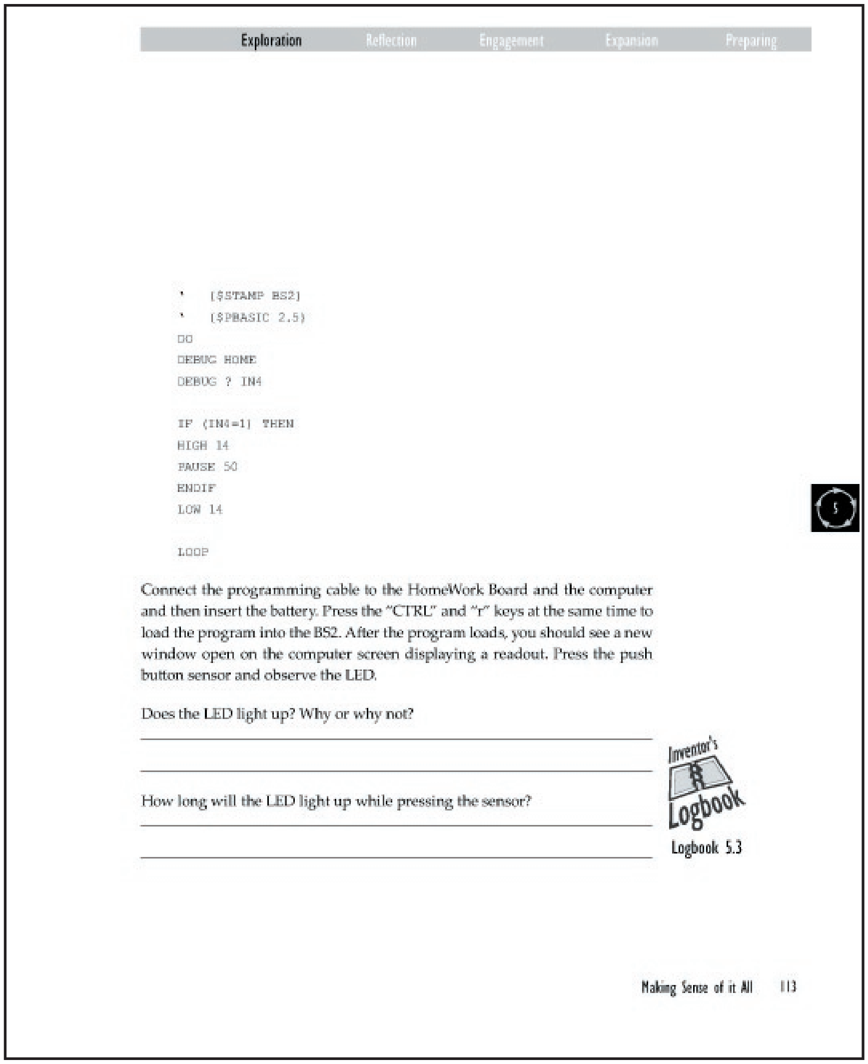
Exploration II

Students are asked to build on their knowledge of sensors and their experience working with the BASIC Stamp HomeWork Board in the previous learning cycle. In teams, students will first construct the Homework Board's project platform with one input (contact sensor) and one output (LED). After they have programmed the BASIC Stamp (BS2) and answered the questions that follow they will get a chance to go through an explanation of the program commands. They will then move onto constructing the project platform with two sensors and one output. Using Boolean logic, students will command the BS2 to respond according to the inputs.



Exploration Reflection Engagement Expansion Preparing

```
'   {$STAMP BS2}
'   {$PBASIC 2.5}
DO
DEBUG HOME
DEBUG ? IN4

IF (IN4=1) THEN
HIGH 14
PAUSE 50
ENDIF
LOW 14

LOOP
```

Connect the programming cable to the HomeWork Board and the computer and then insert the battery. Press the "CTRL" and "r" keys at the same time to load the program into the BS2. After the program loads, you should see a new window open on the computer screen displaying a readout. Press the push button sensor and observe the LED.

Does the LED light up? Why or why not?

How long will the LED light up while pressing the sensor?

Inventor's Logbook

Logbook 5.3

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- Does the LED light up? Why or why not?
  The LED should light up when the push-button is pressed after the program loads.

  If the push-button is pressed for a longer period of time the LED will blink. The LED blinks because it is being turned on (HIGH14) and off (LOW14) repeatedly, very quickly (50 ms). The program will continue to repeat (LOOP). If the LED is not lighting up when the push-button is pressed students may have constructed the circuit incorrectly or entered the wrong program commands.

- How long will the LED light up while pressing the sensor?
  The LED should light up (and blink) continuously.

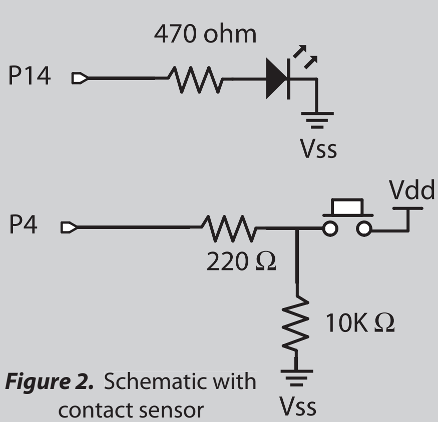


Figure 2. Schematic with contact sensor

Students will be constructing their circuits using schematic drawings. Please refer them to the previous learning cycle for guidance on interpreting the schematic symbols being used.

An Explanation of the Program

```
DEBUG HOME
```

The "**DEBUG HOME**" command instructs the computer to clear the screen in the new window that opens after the program loads each time.

```
DEBUG ? IN 4
```

The "**DEBUG ?**" command displays the value of the statement that follows on the screen in the new window. In this case it displays the pin (IN) value of pin 4.

```
IF (IN4=1) THEN
```

An "**IF..THEN**" command instructs the BS2 that if the conditions are met by the statement following the IF command, then it can proceed to the next operation. This program (IN4=1) follows the IF command, which means if pin 4 is 1 or activated (closed or on), then the next operation should be followed.

```
HIGH 14
```

The next operation, "**HIGH**," instructs the BS2 to activate (turn on) pin 14, which turns on the LED.

```
PAUSE 50
```

The "**PAUSE**" command delays the execution of the next program, in this case for 50 ms.

```
ENDIF
```

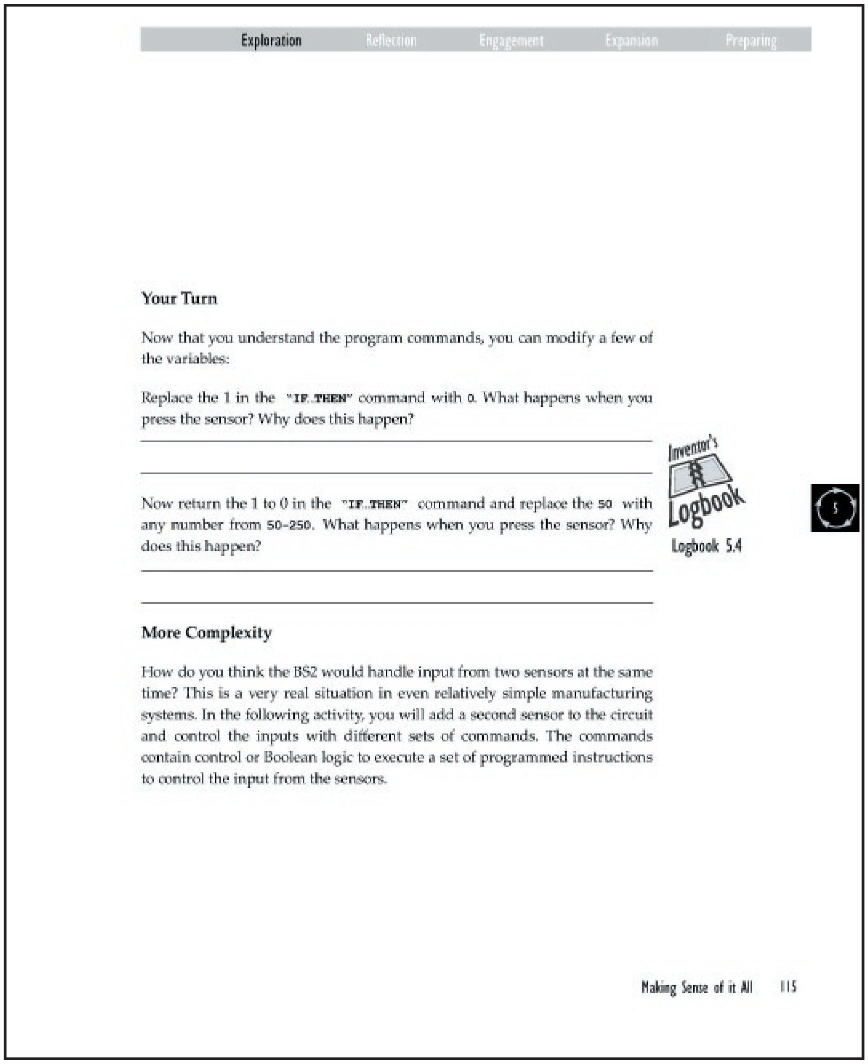
"**ENDIF**" tells the BS2 to end the IF operation listed above (IN4=1).

```
LOW14
```

"**LOW**" instructs the BS2 to deactivate (turn off) the pin number that follows (14).

```
LOOP
```

The "**LOOP**" command simply repeats the above program.


Exploration Reflection Engagement Expansion Preparing

Your Turn

Now that you understand the program commands, you can modify a few of the variables:

Replace the 1 in the "**IF..THEN**" command with 0. What happens when you press the sensor? Why does this happen?

Inventor's Logbook

Logbook 5.4

Now return the 1 to 0 in the "**IF..THEN**" command and replace the 50 with any number from 50-250. What happens when you press the sensor? Why does this happen?

More Complexity

How do you think the BS2 would handle input from two sensors at the same time? This is a very real situation in even relatively simple manufacturing systems. In the following activity, you will add a second sensor to the circuit and control the inputs with different sets of commands. The commands contain control or Boolean logic to execute a set of programmed instructions to control the input from the sensors.

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Students are asked to manipulate a few of the variables to better understand the commands being used in the program.

- Replace the 1 in the "**IF...THEN**" command with 0. What happens when you press the sensor? Why does this happen?
  The LED should turn off when the sensor is pressed and be on when it is not pressed. Pin4 will be activated (on) until the sensor is pressed turning it off (0).

- Now return the 1 to 0 in the "**IF...THEN**" command and replace the 50 with any number from 50-250. What happens when you press the sensor? Why does this happen?
  Replacing 50 with a larger number will delay the blinking of the LED while pressing the push-button. The **PAUSE** *command programs how long Pin14 will be on and off. Thus, the LED will blink while the push-button is pressed because it is continuously looping through turning Pin14, the LED, on and off.*

5

More Complexity with Boolean Logic

Students will use Boolean Logic to program two sensors and one LED. They will first be introduced to two basic logic functions: AND and OR. Then they will have an opportunity to use each of these functions in programming the input from the two sensors. You may want to spend some time going through each function because students will be using these in the *Engagement* phase of this learning cycle.

Boolean Logic

As circuits get more complex, it becomes necessary to manage the logic of the circuit's outputs. Boolean logic is often embedded into programs designed to control the outputs of a circuit. An understanding of Boolean logic is essential for programming the BS2 with multiple sensors. For the following activity, there are two basic logic functions used.

The AND Function

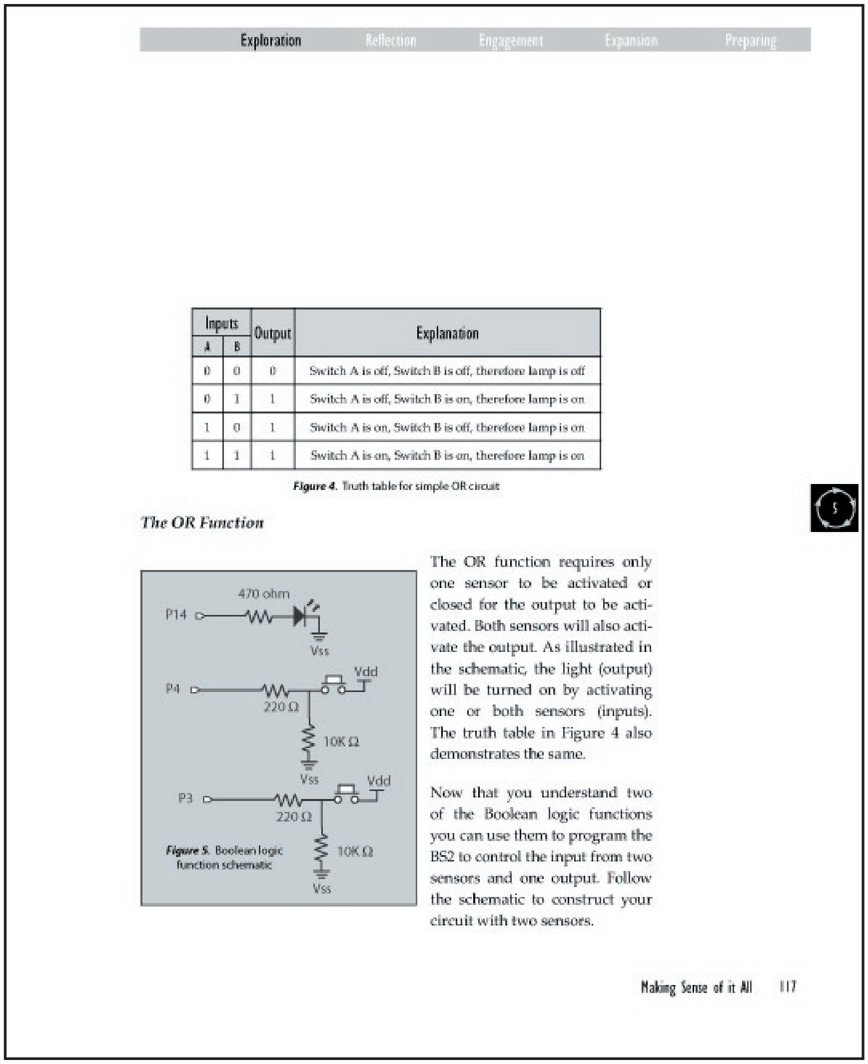
The AND function requires both sensors to be either activated or closed in order for the output to be activated. As illustrated in the schematic below, both A and B sensors (input) have to be closed for the light (output) to be turned on. Another way to understand the AND function is through a truth table. Figure 3 uses binary notation in a truth table to illustrate the AND function. 0 represents de-energized or open and 1 represents energized or closed.

Inputs		Output	Explanation
A	B		
0	0	0	Switch A is off, Switch B is off, therefore lamp is off
0	1	0	Switch A is off, Switch B is on, therefore lamp is off
1	0	0	Switch A is on, Switch B is off, therefore lamp is off
1	1	1	Switch A is on, Switch B is on, therefore lamp is on

Figure 3. Truth table for simple AND circuit

Inputs		Output	Explanation
A	B		
0	0	0	Switch A is off, Switch B is off, therefore lamp is off
0	1	0	Switch A is off, Switch B is on, therefore lamp is off
1	0	0	Switch A is on, Switch B is off, therefore lamp is off
1	1	1	Switch A is on, Switch B is on, therefore lamp is on

Figure 3. Truth table for simple AND circuit



Exploration Reflection Engagement Expansion Preparing

Inputs		Output	Explanation
A	B		
0	0	0	Switch A is off, Switch B is off, therefore lamp is off
0	1	1	Switch A is off, Switch B is on, therefore lamp is on
1	0	1	Switch A is on, Switch B is off, therefore lamp is on
1	1	1	Switch A is on, Switch B is on, therefore lamp is on

Figure 4. Truth table for simple OR circuit

The OR Function

The OR function requires only one sensor to be activated or closed for the output to be activated. Both sensors will also activate the output. As illustrated in the schematic, the light (output) will be turned on by activating one or both sensors (inputs). The truth table in Figure 4 also demonstrates the same.

Now that you understand two of the Boolean logic functions you can use them to program the BS2 to control the input from two sensors and one output. Follow the schematic to construct your circuit with two sensors.

Figure 5. Boolean logic function schematic

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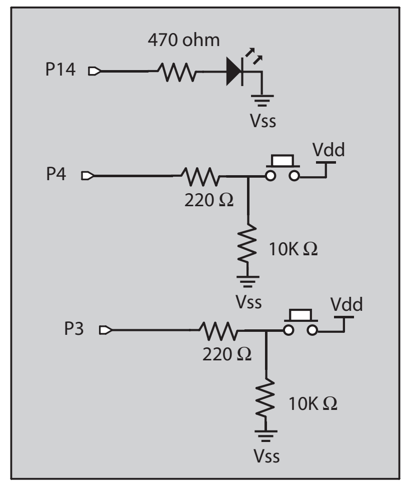


Figure 5. Boolean logic function schematic

Inputs		Output	Explanation
A	B		
0	0	0	Switch A is off, Switch B is off, therefore lamp is off
0	1	1	Switch A is off, Switch B is on, therefore lamp is on
1	0	1	Switch A is on, Switch B is off, therefore lamp is on
1	1	1	Switch A is on, Switch B is on, therefore lamp is on

Figure 4. Truth table for simple OR circuit

Notes:

The AND Function

```
'   {$STAMP BS2}
'   {$PBASIC 2.5}
DO
DEBUG HOME
DEBUG ? IN4
DEBUG ? IN3

IF (IN4=1) AND (IN3=1) THEN
HIGH 14
PAUSE 50

ENDIF
LOW 14

LOOP
```

An Explanation of the AND Function

```
IF (IN4=1) AND (IN3=1) THEN
```

This **"IF..THEN"** command uses the AND logic function. The command instructs the BS2 to do the next operation if pin 4 and pin 3 are on (1). So, if pin 4 and pin 3 are activated (turned on), then pin 14 is activated **(HIGH 14)** and the LED turns on.

The OR Function

```
'   {$STAMP BS2}
'   {$PBASIC 2.5}
DO
DEBUG HOME
DEBUG ? IN4
DEBUG ? IN 3

IF (IN4=1) OR (IN3=1) THEN
HIGH 14
PAUSE 50

ENDIF
LOW 14

LOOP
```

An Explanation of the OR Function

```
IF (IN4=1) AND (IN3=1) THEN
```

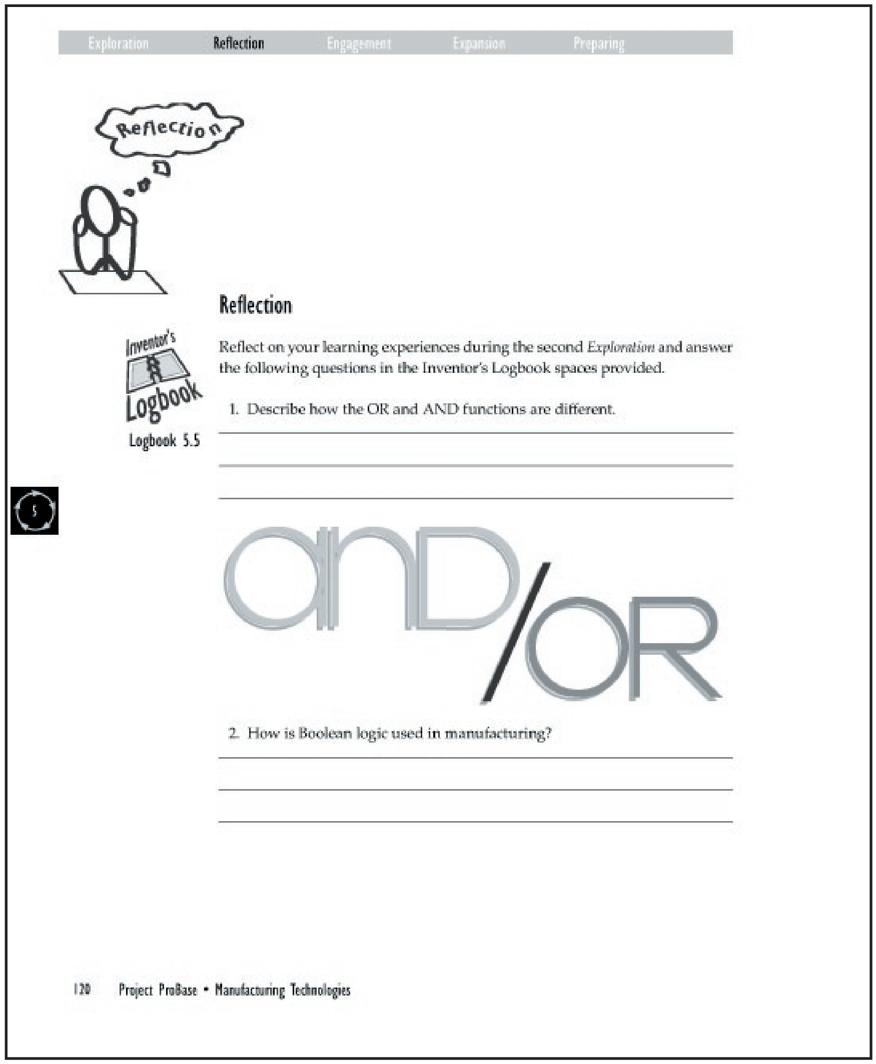
This "**IF..THEN**" command uses the OR function to control the input from the two sensors. If pin 4 or pin 3 is activated (1) then the BS2 will go to the next command, **HIGH 14**. So, if either pin 4 or pin 3 is turned on, or if both are turned on at the same time, then pin 14 will be activated and turn on the LED.

Notes:

Reflection

Students should go through each of the following questions in their teams to make sure they understand the OR and AND functions.

1. Describe how the OR and AND functions are different.
   The AND function requires both sensors to be activated or closed in order for the output to be activated. The OR function requires only one sensor to be activated or closed for the output to be activated.


Exploration Reflection Engagement Expansion Preparing

Reflection

Reflection

Inventor's Logbook

Logbook 5.5

Reflect on your learning experiences during the second *Exploration* and answer the following questions in the Inventor's Logbook spaces provided.

1. Describe how the OR and AND functions are different.

and/OR

2. How is Boolean logic used in manufacturing?

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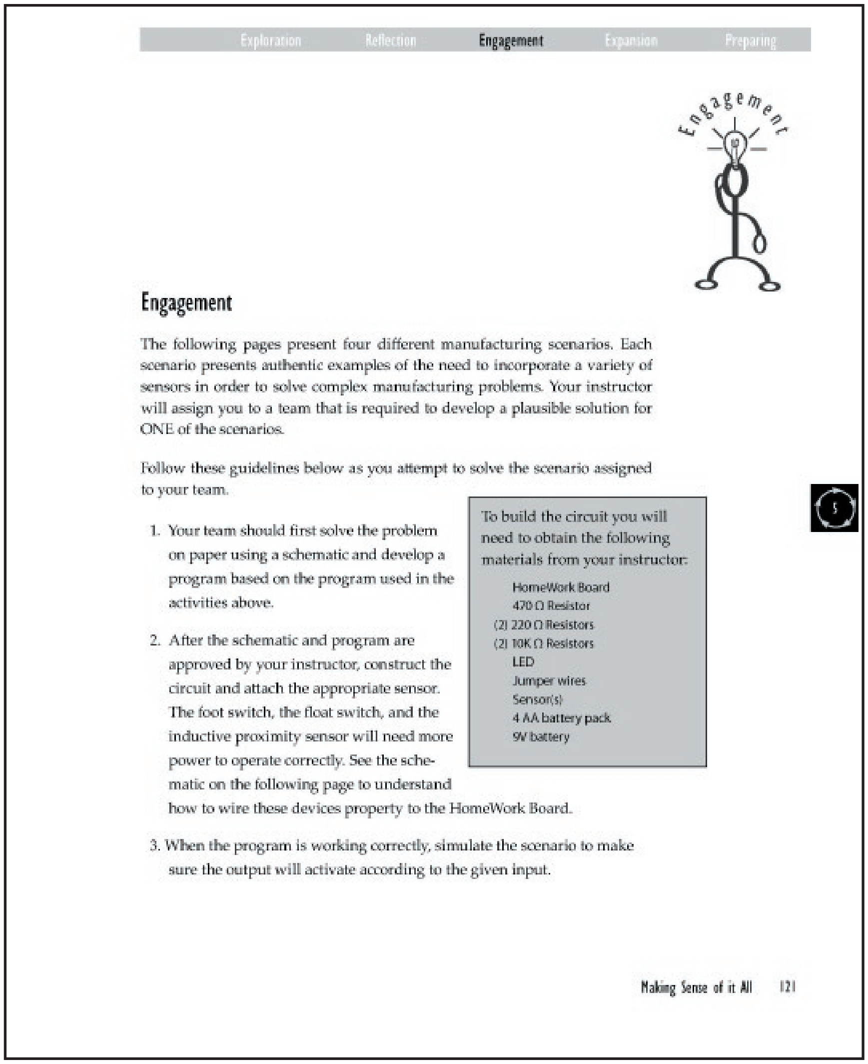
2. How is Boolean logic used in manufacturing?
   There are a variety of examples students can come up with. The Engagement phase provides some authentic examples of the use of a variety of sensors programmed with Boolean logic. For example, for safety reasons many large machines must be operated by employing two different sensors so both hands are free from danger.



Exploration Reflection Engagement Expansion Preparing

Engagement

The following pages present four different manufacturing scenarios. Each scenario presents authentic examples of the need to incorporate a variety of sensors in order to solve complex manufacturing problems. Your instructor will assign you to a team that is required to develop a plausible solution for ONE of the scenarios.

Follow these guidelines below as you attempt to solve the scenario assigned to your team.

1. Your team should first solve the problem on paper using a schematic and develop a program based on the program used in the activities above.
2. After the schematic and program are approved by your instructor, construct the circuit and attach the appropriate sensor. The foot switch, the float switch, and the inductive proximity sensor will need more power to operate correctly. See the schematic on the following page to understand how to wire these devices property to the HomeWork Board.
3. When the program is working correctly, simulate the scenario to make sure the output will activate according to the given input.

To build the circuit you will need to obtain the following materials from your instructor:

HomeWork Board
470 Ω Resistor
(2) 220 Ω Resistors
(2) 10K Ω Resistors
LED
Jumper wires
Sensor(s)
4 AA battery pack
9V battery

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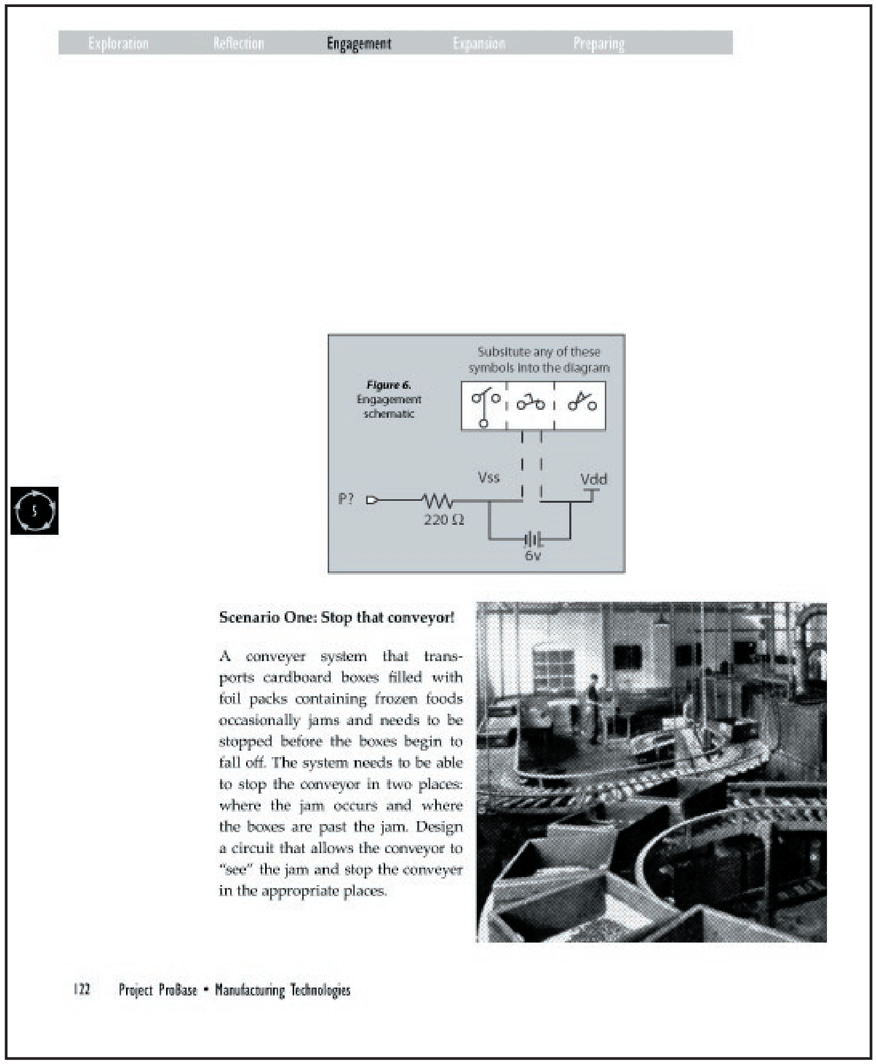
Engagement

Materials needed per team:

BASIC Stamp HomeWork Board
470 Ω Resistor
(2) 220 Ω Resistors
(2) 10K Ω Resistors
LED
Jumper wires
Sensor(s) and switch(es): Students will need to decide which one(s) to use.
4AA battery pack
9V battery

In teams, students are challenged to solve one of the following manufacturing scenarios. They are asked to follow the given guidelines with their solution. The foot switch, the float switch, and the inductive proximity sensor will need more power to operate correctly. See the schematic to understand how to wire these devices property to the HomeWork Board's project platform.



Exploration Reflection Engagement Expansion Preparing

Figure 6. Engagement schematic

Subsitute any of these symbols into the diagram

Vss Vdd

P? 220 Ω 6v

Scenario One: Stop that conveyor!

A conveyer system that transports cardboard boxes filled with foil packs containing frozen foods occasionally jams and needs to be stopped before the boxes begin to fall off. The system needs to be able to stop the conveyor in two places: where the jam occurs and where the boxes are past the jam. Design a circuit that allows the conveyor to "see" the jam and stop the conveyer in the appropriate places.

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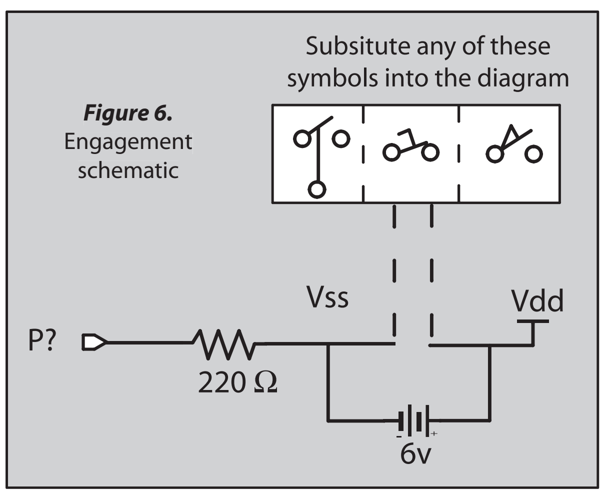


Figure 6.
Engagement
schematic

Scenario Two: Is the tank half full or half empty?

A soft drink beverage company has a recipe that it has followed for more than 100 years. It relies on just the right amount of a secret (liquid) ingredient in every batch of beverage. This ingredient is so important that the company has solicited your team's help to monitor the level of this ingredient in the tank so that it does not run out or is wasted. Design a circuit to monitor the level of this liquid in the storage tank. A light should come on when the tank is becoming empty or getting too full.

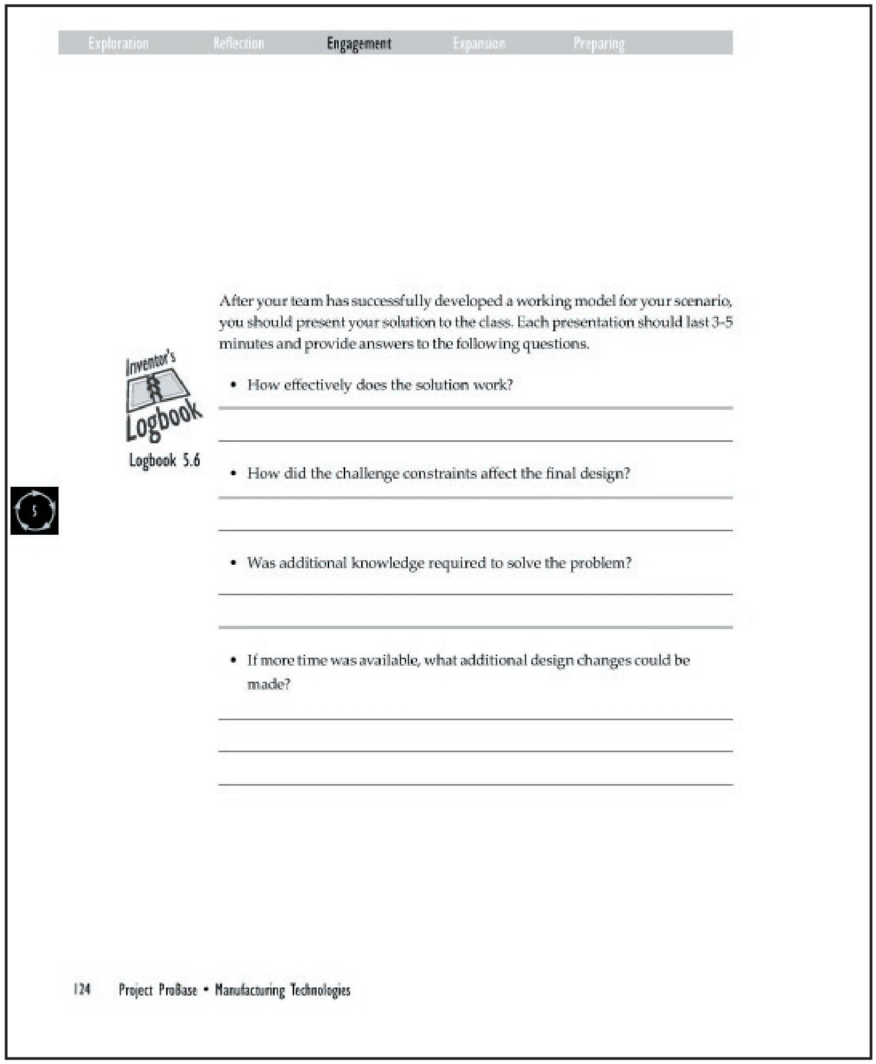
Scenario Three: Safety first!

An outdoor sign manufacturing company just purchased a very large sheet metal shear. The company is concerned about operator safety. Before the machine is delivered, the company wants to have a system in place that requires the operator to have both hands free from the shear before operating a foot switch. Design a circuit to ensure operator safety.

Notes:

After each team has developed a solution they should present it to the class. Each presentation should last 3-5 minutes and provide answers to the following questions.

- How effectively does the solution work?
- How did the challenge constraints affect the design?
- Was additional knowledge required to solve the problem?
- If more time was available, what additional design changes could be made?



Exploration Reflection Engagement Expansion Preparing

Inventor's Logbook

Logbook 5.6

After your team has successfully developed a working model for your scenario, you should present your solution to the class. Each presentation should last 3-5 minutes and provide answers to the following questions.

- How effectively does the solution work?
- How did the challenge constraints affect the final design?
- Was additional knowledge required to solve the problem?
- If more time was available, what additional design changes could be made?

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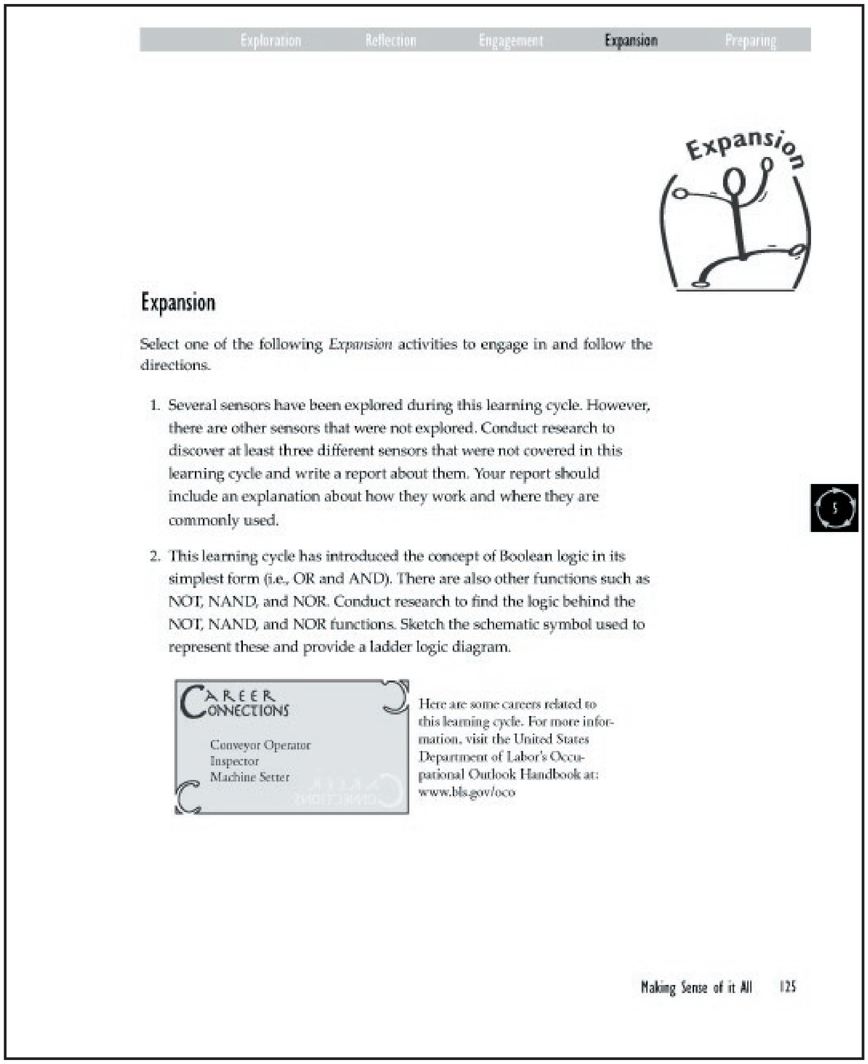

Exploration Reflection Engagement Expansion Preparing

Expansion

Expansion

Select one of the following *Expansion* activities to engage in and follow the directions.

1. Several sensors have been explored during this learning cycle. However, there are other sensors that were not explored. Conduct research to discover at least three different sensors that were not covered in this learning cycle and write a report about them. Your report should include an explanation about how they work and where they are commonly used.
2. This learning cycle has introduced the concept of Boolean logic in its simplest form (i.e., OR and AND). There are also other functions such as NOT, NAND, and NOR. Conduct research to find the logic behind the NOT, NAND, and NOR functions. Sketch the schematic symbol used to represent these and provide a ladder logic diagram.

CAREER CONNECTIONS

Conveyor Operator
Inspector
Machine Setter

Here are some careers related to this learning cycle. For more information, visit the United States Department of Labor's Occupational Outlook Handbook at: www.bls.gov/oco

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Expansion

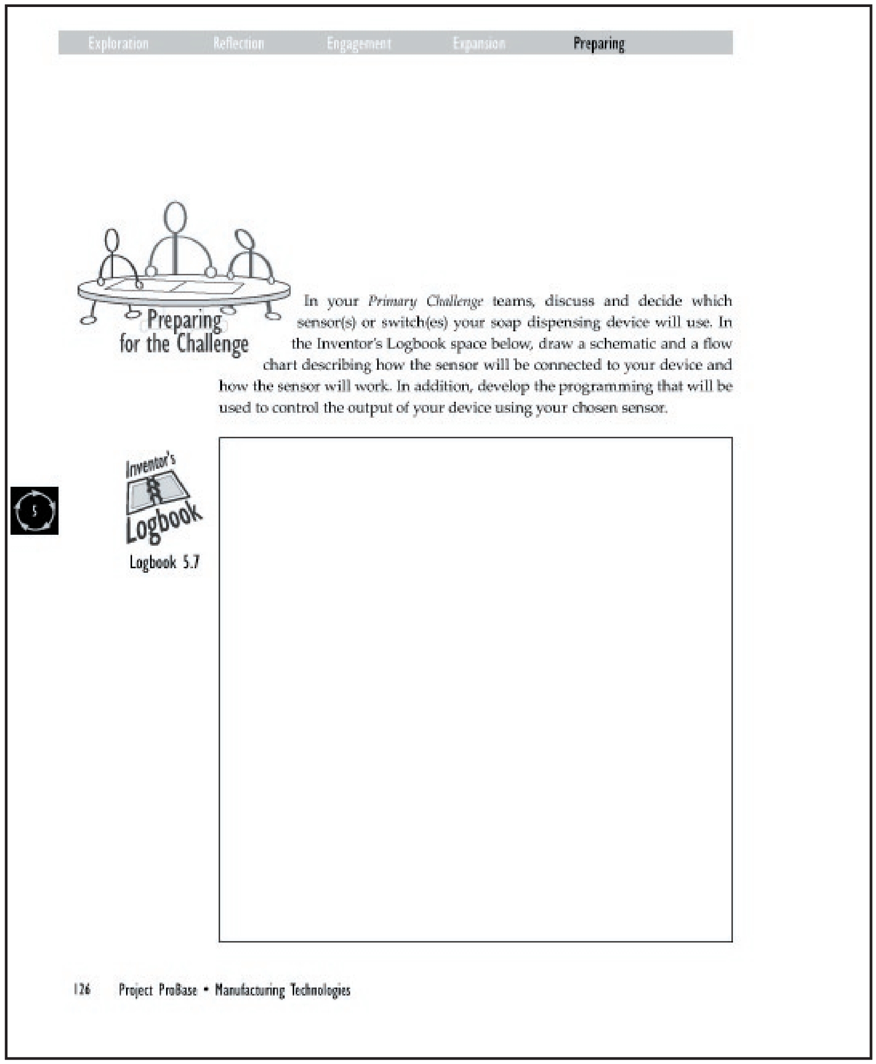
Although not required, these *Expansion* activities are designed to cause teams to delve deeper into the concepts explored in this learning cycle.

1. Several sensors have been explored during this learning cycle. However, there are other sensors that were not explored. Conduct research to discover at least three different sensors that were not covered in this learning cycle and write a report about them. Your report should include an explanation about how they work and where they are commonly used.
2. This learning cycle has introduced the concept of Boolean logic in its simplest form (i.e., OR and AND). There are also other functions such as NOT, NAND and NOR. Conduct research to find the logic behind the NAND and NOR gate. Sketch the schematic symbols used to represent these gates and provide the ladder logic diagram.

5

Preparing for the Challenge

Progress on a solution to the *Primary Challenge* is an important consideration of this learning cycle. In their *Primary Challenge* teams, students are asked to discuss and decide which sensor(s) or switch(es) their soap dispensing device will use. They are asked to draw a schematic and a flow chart in the space provided describing how the sensor will be connected to their device and how the sensor will work. In addition, they should develop the programming that will be used to control the output of their device using their chosen sensor.



Preparing for the Challenge

In your *Primary Challenge* teams, discuss and decide which sensor(s) or switch(es) your soap dispensing device will use. In the Inventor's Logbook space below, draw a schematic and a flow chart describing how the sensor will be connected to your device and how the sensor will work. In addition, develop the programming that will be used to control the output of your device using your chosen sensor.

Inventor's Logbook

Logbook 5.7

Student Assessment

An assessment rubric has been developed for the *Exploration* and *Engagement* activities. Feel free to change this rubric to better suit your particular needs.

Making Sense of it All

Element	Criteria				Points
	4	3	2	1	
Exploration I and II	Completed every activity with exceptional quality.	Completed activities with above average quality.	Completed most of the activities with average quality.	Completed some of the activities and/or with below average quality.	
Engagement	Created an exceptional solution to one of the scenarios.	Created an above average solution to one of the scenarios.	Created an average solution or chose an inappropriate sensor.	Did not create a solution or did not follow the guidelines.	
Inventor's Logbook Entries	Answered all questions correctly and in detail.	Answered all questions correctly and in some detail.	Answered most questions correctly.	Answered few questions correctly.	
Expansion	Completed one of the activities with exceptional quality.	Completed one of the activities with above average quality.	Completed one of the activities with average quality.	Did not complete one of the activities or was poor quality.	
				Totals	

5

Learning Cycle Six

It's NOT a Relay Race

It's NOT a Relay Race

Introduction

In this learning cycle, students will be focusing on applications of electromagnetic relays and how they work.

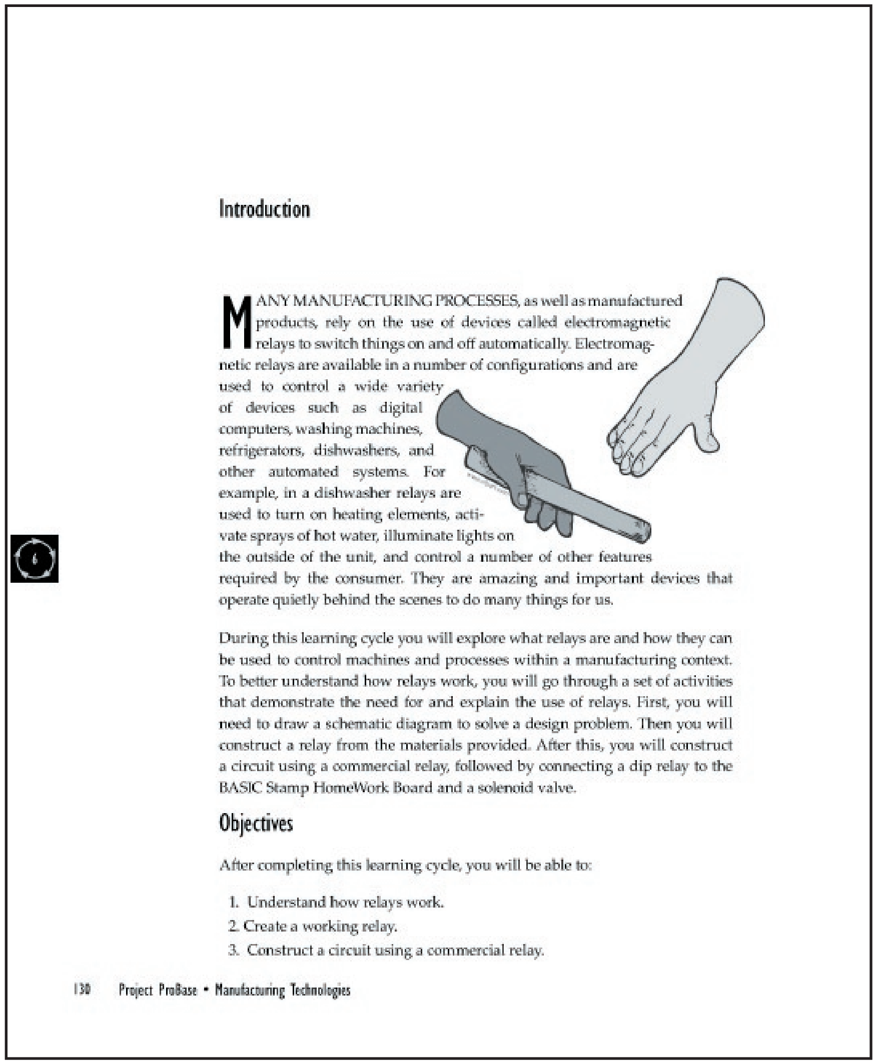
Students are asked to solve a design problem with a schematic drawing. They are then introduced to a better solution to the problem using a relay. Students will build a relay and then complete activities using two different types of commercial relays.

Objectives and Essential Questions

1. Understand how relays work.
Essential Question 4b: What are the key elements of the various technological systems and what are the relationships between these systems?

2. Create a working relay.
Essential Question 9d: How is technological instrumentation used to measure, calculate, manipulate, and predict the actions of technological devices and systems?

3. Construct a circuit using a commercial relay.
Essential Question 9a: How are technologies used to control devices and systems?



Introduction

MANY MANUFACTURING PROCESSES, as well as manufactured products, rely on the use of devices called electromagnetic relays to switch things on and off automatically. Electromagnetic relays are available in a number of configurations and are used to control a wide variety of devices such as digital computers, washing machines, refrigerators, dishwashers, and other automated systems. For example, in a dishwasher relays are used to turn on heating elements, activate sprays of hot water, illuminate lights on the outside of the unit, and control a number of other features required by the consumer. They are amazing and important devices that operate quietly behind the scenes to do many things for us.

During this learning cycle you will explore what relays are and how they can be used to control machines and processes within a manufacturing context. To better understand how relays work, you will go through a set of activities that demonstrate the need for and explain the use of relays. First, you will need to draw a schematic diagram to solve a design problem. Then you will construct a relay from the materials provided. After this, you will construct a circuit using a commercial relay, followed by connecting a dip relay to the BASIC Stamp HomeWork Board and a solenoid valve.

Objectives

After completing this learning cycle, you will be able to:

1. Understand how relays work.
2. Create a working relay.
3. Construct a circuit using a commercial relay.

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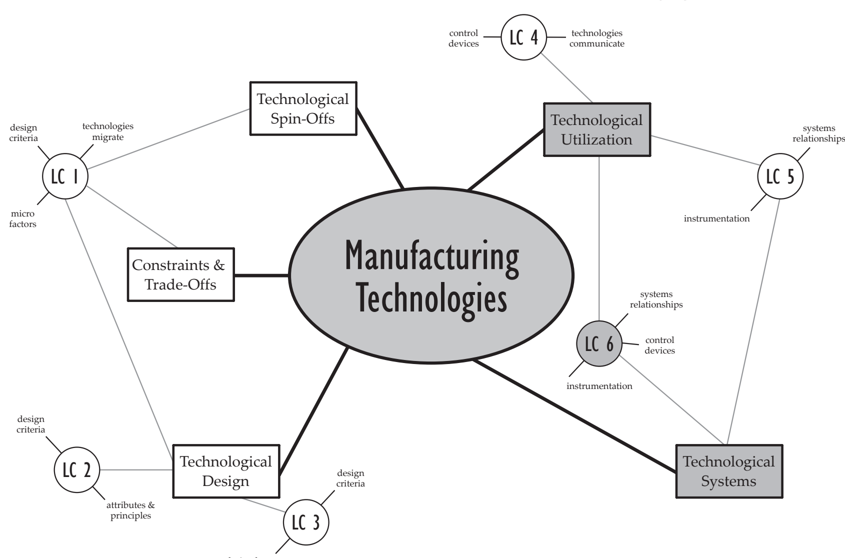
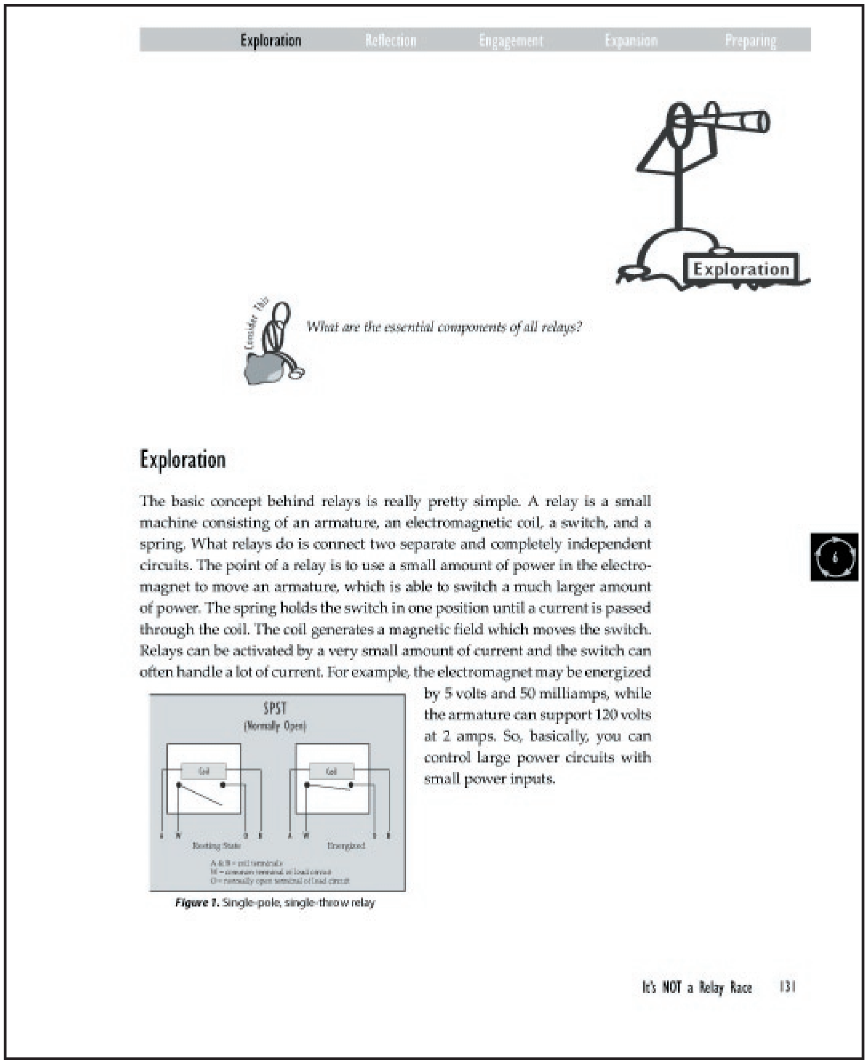
Manufacturing Technologies
Learning Cycle Six Concept Map




Exploration Reflection Engagement Expansion Preparing

What are the essential components of all relays?

Exploration

The basic concept behind relays is really pretty simple. A relay is a small machine consisting of an armature, an electromagnetic coil, a switch, and a spring. What relays do is connect two separate and completely independent circuits. The point of a relay is to use a small amount of power in the electromagnet to move an armature, which is able to switch a much larger amount of power. The spring holds the switch in one position until a current is passed through the coil. The coil generates a magnetic field which moves the switch. Relays can be activated by a very small amount of current and the switch can often handle a lot of current. For example, the electromagnet may be energized by 5 volts and 50 milliamps, while the armature can support 120 volts at 2 amps. So, basically, you can control large power circuits with small power inputs.

Figure 1. Single-pole, single-throw relay

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Facility Requirements

No special facility requirements are required as long as students have access to computers with Internet access and a place to design and build their relay models.

Equipment and Materials

Based on a class of 28 students:

Wood nails, and screws

Sheet metal

(7) Ink pen springs

(7) switches

(7) LEDs

(7) 2 AA batteries and holder or 9V batteries and holder

(7) 1 AA battery and holder

Electrical wire

(7) Clear (spade-terminal) relay, 12 VDC suggested source McMaster-Carr part #7266K41

(7) Dip relay, 5VDC suggested source Jameco #138430 CP

(28) Lantern batteries

(7) Push-button sensors

Jumper wires

(7) Alligator clip sets

(7) Solenoid valve, 24VDC suggested source MSC Industrial Supplies Order #07420946

BASIC Stamp HomeWork Board

BASIC Stamp serial programming cable

BASIC Stamp Editor software

Estimated number of 50-minute class periods: **5**

Suggested Daily Outline

Day One	Day Two
Exploration	*Exploration*
Day Three	**Day Four**
Reflection, Engagement	*Engagement*
Day Three	
Engagement, Preparing for the Challenge	

The inner workings of a relay are best described by a model. All electromagnetic relays contain an electric coil powered by AC (alternating current) or DC (direct current). When the coil is energized, it generates a magnetic force that actuates or triggers a switch mechanism. The electromagnetic force relays the action from one circuit to another by activating the load circuit. These circuits, however, must not touch and do not become one continuous circuit. The load circuit is the circuit that operates the device such as a motor, light, or other relay. Figure 1 is a pictorial diagram of a simple, normally open single-pole, single-throw relay.

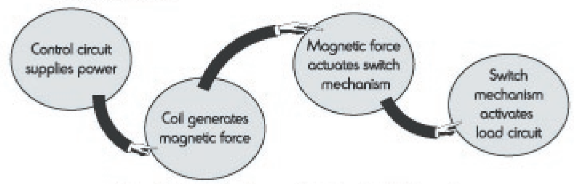


Figure 2. Functional flow diagram of a single-pole, single-throw relay

The term single pole (SP) contact means that all contacts in the relay connect in one position to a common contact (see Figure 1). The term single throw (ST) contact means that the relay's contact is open in one position and closed in the other. Single-pole, single-throw (SPST) relays can control only one load circuit. Study the functional flow diagram in Figure 2 to get a better understanding of how single-pole, single-throw relays work.

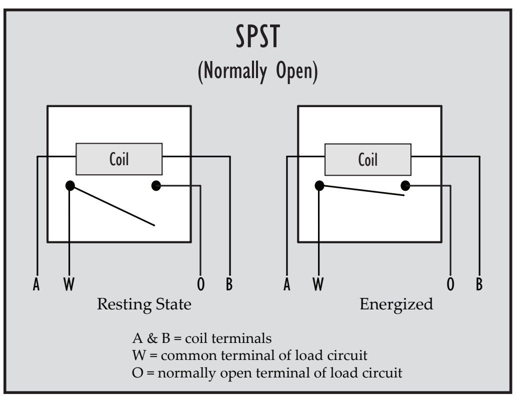
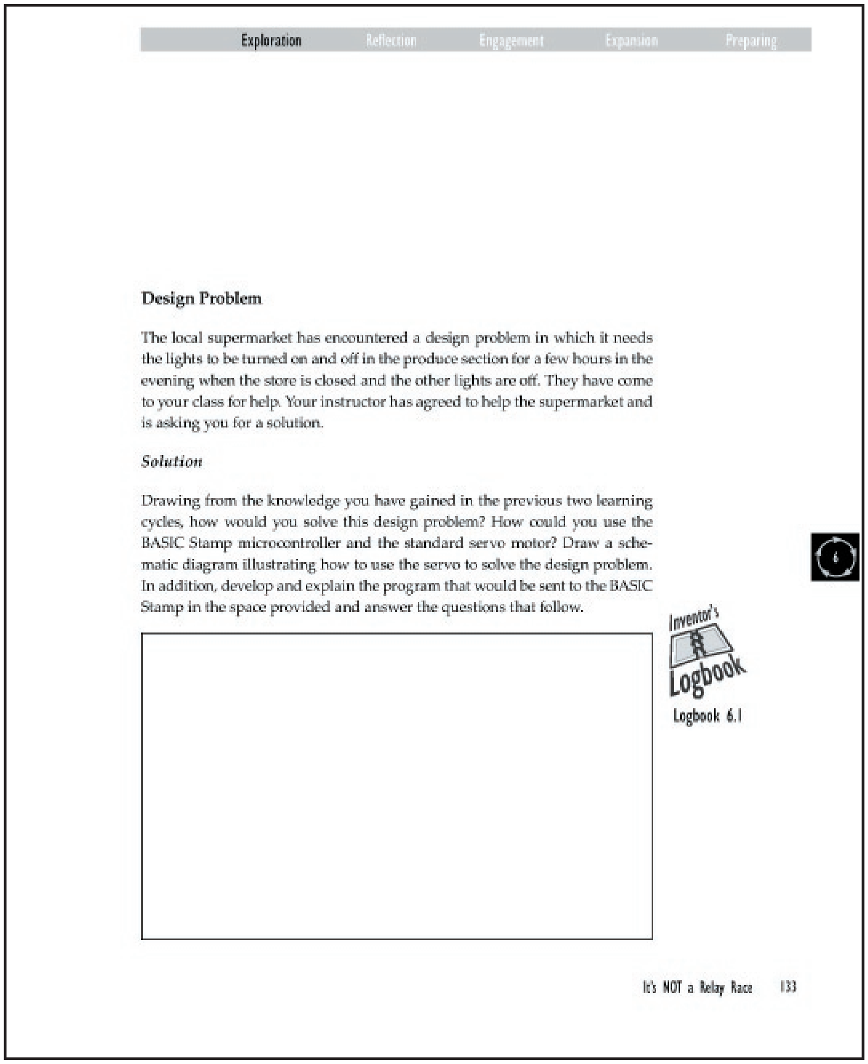


Figure 1. Single pole, single throw relay

Exploration

The first part of the *Exploration* is an introduction to the basics of relays. The activities that follow allow for an understanding of why relays are used and how they work. Students are asked to design a solution using the servo motor, which is not the most efficient method. After they have solved the problem with a schematic, a relay is revealed as the better solution. Students are then asked to create a working relay from the materials provided.


Exploration Reflection Engagement Expansion Preparing

Design Problem

The local supermarket has encountered a design problem in which it needs the lights to be turned on and off in the produce section for a few hours in the evening when the store is closed and the other lights are off. They have come to your class for help. Your instructor has agreed to help the supermarket and is asking you for a solution.

Solution

Drawing from the knowledge you have gained in the previous two learning cycles, how would you solve this design problem? How could you use the BASIC Stamp microcontroller and the standard servo motor? Draw a schematic diagram illustrating how to use the servo to solve the design problem. In addition, develop and explain the program that would be sent to the BASIC Stamp in the space provided and answer the questions that follow.

Inventor's Logbook

Logbook 6.1

It's NOT a Relay Race 133

Assign the students in teams of 3 or 4 and have them follow the constraints listed below:

1. The power source for the control circuit and load circuit must not exceed 3 volts DC.

2. The control circuit and load circuit must have different power sources and different voltages.

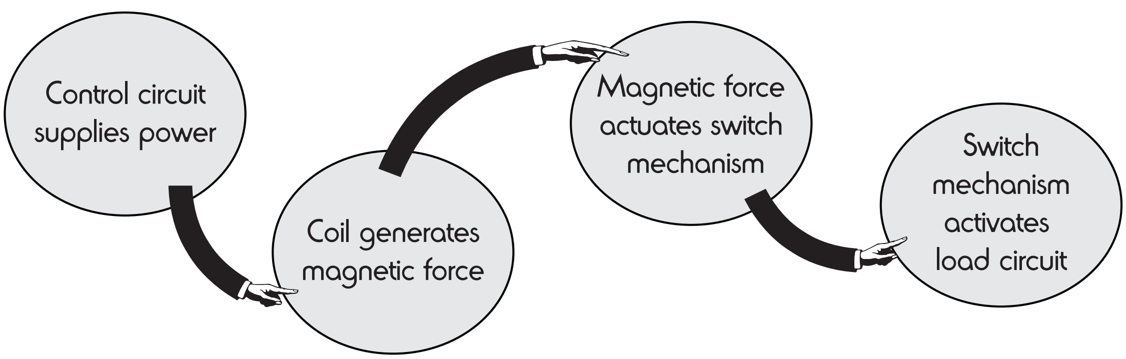


Figure 2. Functional flow diagram of a single-pole, single-throw relay

Inventor's Logbook

Logbook 6.2

1. Do you foresee problems with this solution?

2. If you had access to other equipment besides the servo motor, what would you use?

As you have probably discovered while designing a solution to the supermarket's problem, the use of a servo motor to perform this function is perhaps not the best solution. What would be a more efficient way to have the light switch turn on and off without using the servo motor or by turning it on and off manually?

Safety

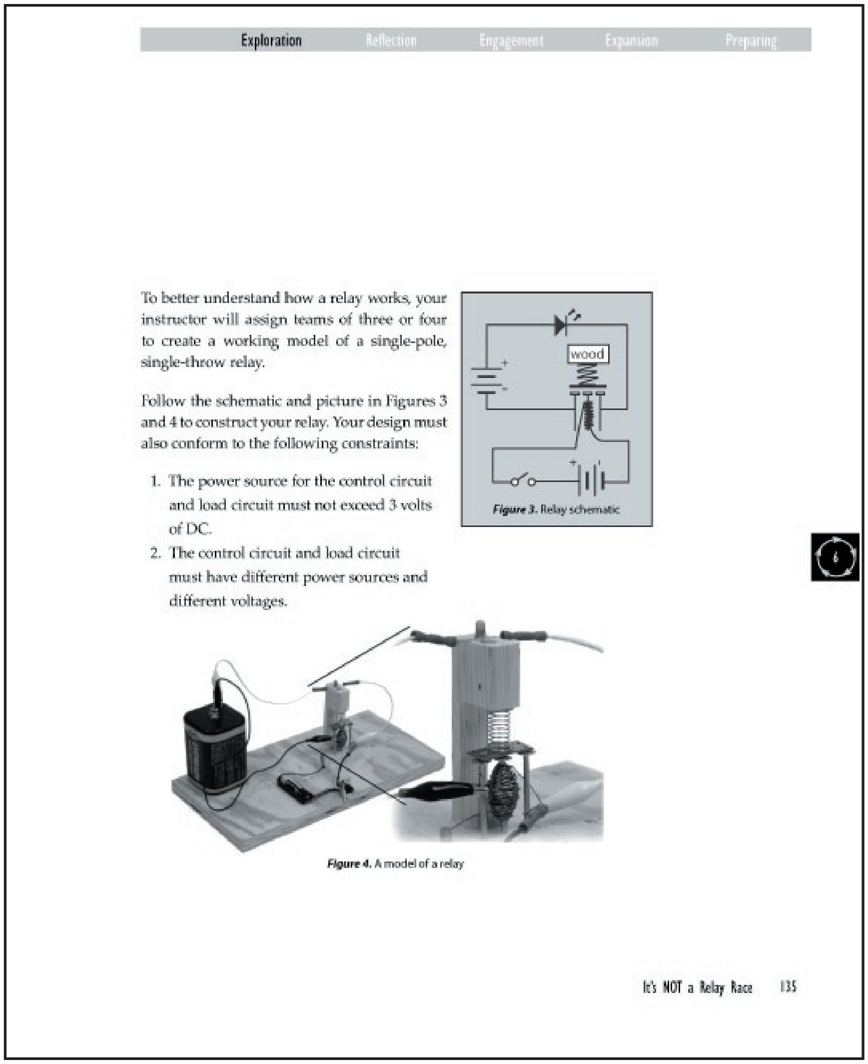
Be careful not to directly short out the battery. Doing so will melt the insulation on the wired.

A Better Solution

A relay could be used to solve this design problem. The relay would be a more compact and efficient solution than the servo. A relay would not only replace the servo, but it would also allow for more power to be used to flip the switch.

Obtain from your instructor the following materials:

- Wood, nails, and screws
- Ink pen spring
- Sheet metal
- Switch and LED
- Batteries and holder
- Electrical wire


Exploration Reflection Engagement Expansion Preparing

To better understand how a relay works, your instructor will assign teams of three or four to create a working model of a single-pole, single-throw relay.

Follow the schematic and picture in Figures 3 and 4 to construct your relay. Your design must also conform to the following constraints:

1. The power source for the control circuit and load circuit must not exceed 3 volts of DC.
2. The control circuit and load circuit must have different power sources and different voltages.

Figure 3. Relay schematic

Figure 4. A model of a relay

It's NOT a Relay Race 135

Teaching Tips

Due to time constraints and the amount of resources needed, you may want to complete this activity through a demonstration. You may decide to build the relay and demonstrate it along with a clear housed industrial relay.

A Better Solution

Students are then introduced to commercial relays and asked to construct a circuit using a clear miniature spade-terminal relay. They should follow the schematic provided and observe the electromagnet within the relay working.

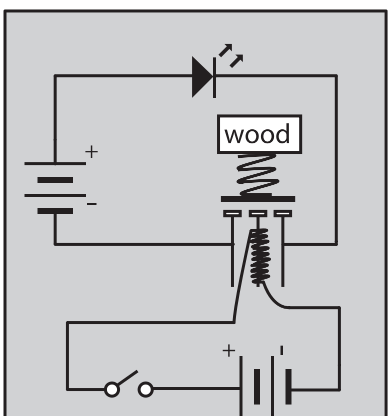


Figure 3. Relay schematic

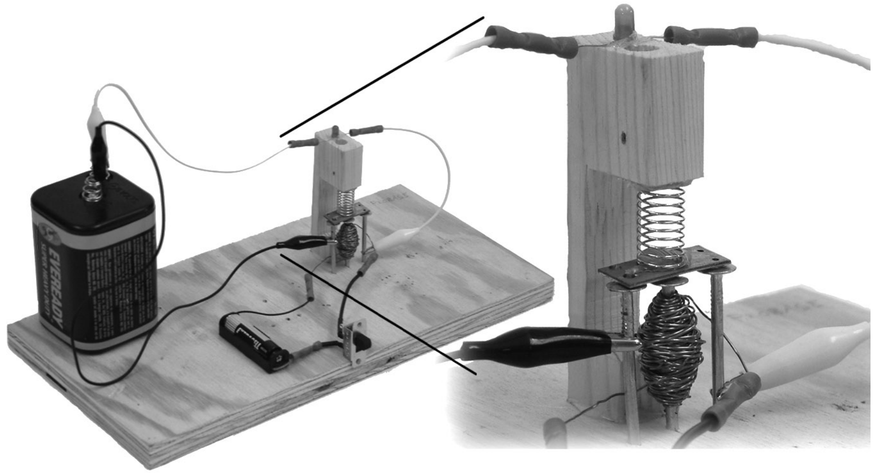


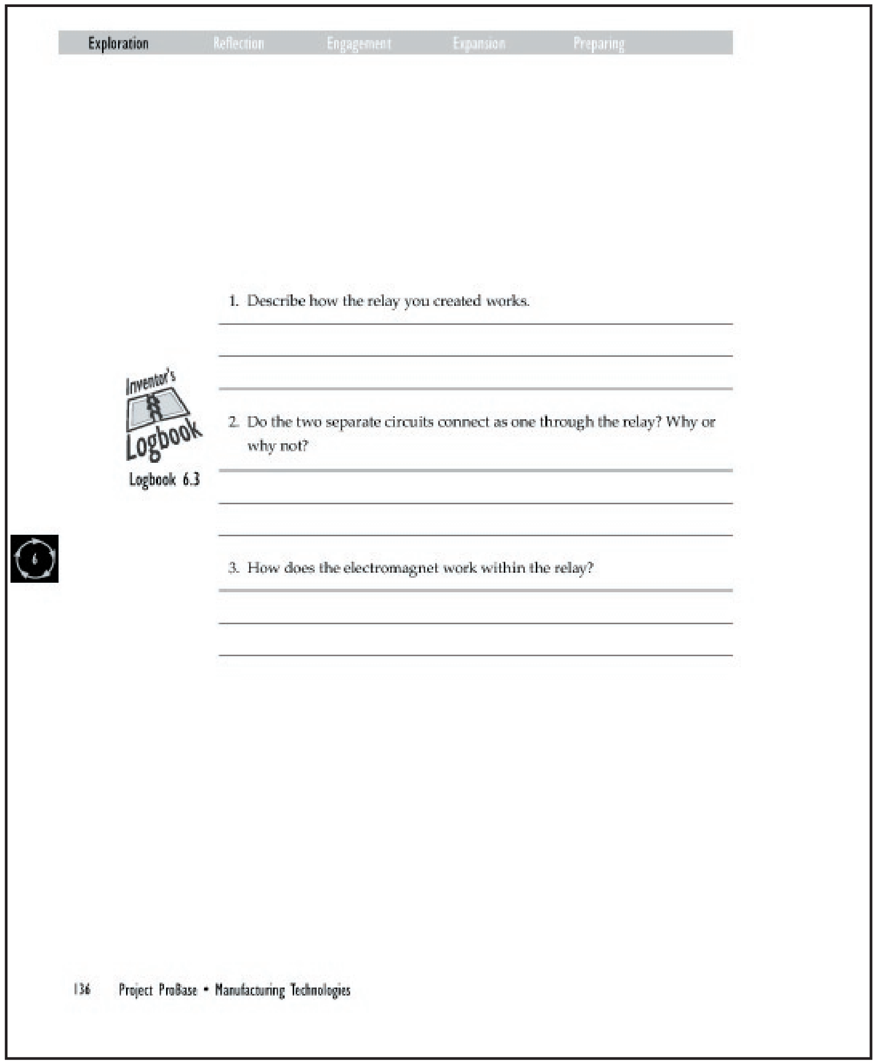
Figure 4. A model of a relay

Students are asked the following questions:

1. Describe in your own words how the relay you created works.
   Students should describe that by using a small amount of power to activate an electromagnet, a relay is able to activate a much larger amount of power for a separate circuit.

2. Do the two separate circuits connect and become one through the relay? Why or why not?
   No, the separate circuits never connect; that would blow the lower voltage circuit.

3. How does the electromagnet work within the relay?
   All electromagnetic relays contain an electric coil that, when energized, generates a magnetic force that actuates or triggers a switch mechanism.



Exploration Reflection Engagement Expansion Preparing

Inventor's Logbook

Logbook 6.3

1. Describe how the relay you created works.

2. Do the two separate circuits connect as one through the relay? Why or why not?

3. How does the electromagnet work within the relay?

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Exploration Reflection Engagement Expansion Preparing

As you have discovered, the relay you have created is not very small. Like most electronic devices these days, commercial relays are much more compact and are available to meet a wide variety of demands and applications. Commercial relays also have the advantage of controlling several variables at the same time. The voltage and current that is needed to activate the armature varies, as does the maximum voltage and current that can run through the armature and the armature contacts. You can also specify whether the contact is normally open or normally closed.

By using two lantern batteries, you can construct a circuit using a clear commercial relay. Follow the schematic to build the new circuit using the alligator clips and wire to connect the components and observe the electromagnet within the relay working.

Obtain from your instructor the following materials:

- Clear commercial relay
- (4) Lantern batteries
- Alligator clips and wire
- Push-button sensor
- Jumper wires
- LED

Safety

Be careful not to directly short out the battery. Doing so will melt the insulation on the wires!

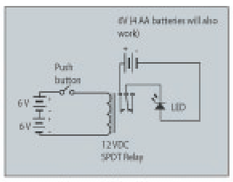


Figure 5. Relay schematic

Safety

Caution: Be careful not to directly short out the battery. Doing so will melt the insulation on the wires!

6

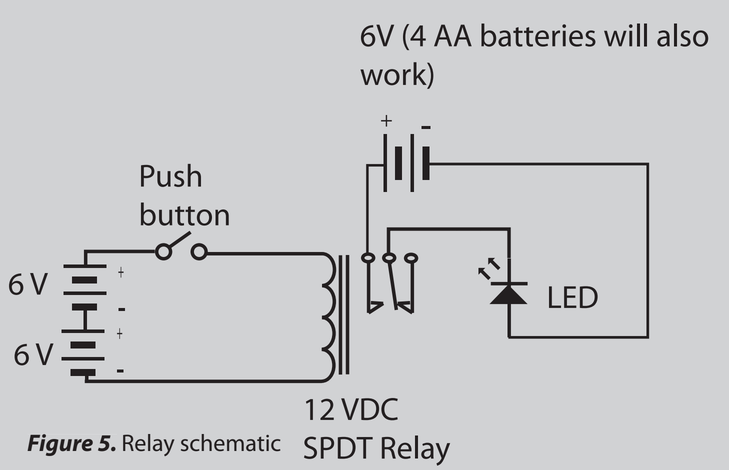


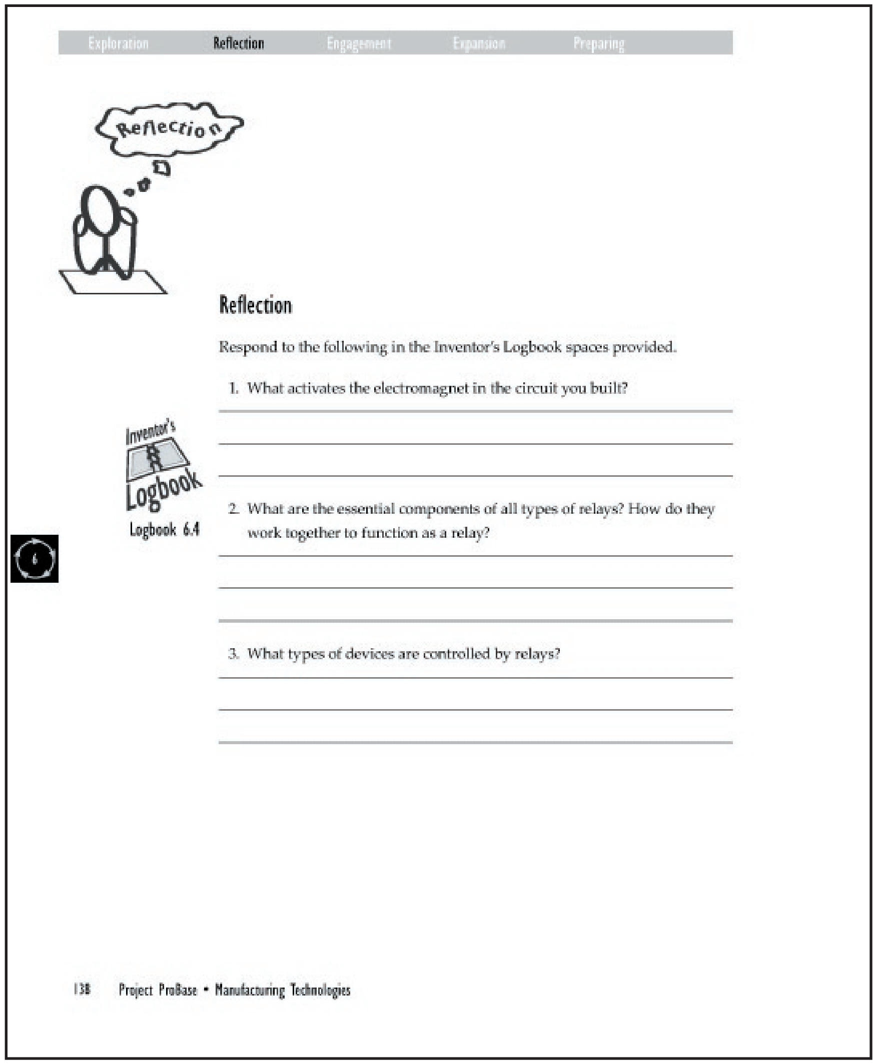
Figure 5. Relay schematic

Reflection

The students will be responding to the following questions in the Inventor's Logbook space within their text:

1. What activates the electromagnet in the circuit you built?
   The electromagnet is activated by the lower voltage and moves the armature, which causes the switch to activate the other circuit.

2. What are the essential components of all types of relays? How do they work together to function as a relay?
   The essential components of all relays are the electromagnet, armature, spring, and electrical contacts. The spring holds the switch in position until a current is passed through the coil, which generates the magnet to move the switch.



Exploration Reflection Engagement Expansion Preparing

Reflection

Respond to the following in the Inventor's Logbook spaces provided.

1. What activates the electromagnet in the circuit you built?
2. What are the essential components of all types of relays? How do they work together to function as a relay?
3. What types of devices are controlled by relays?

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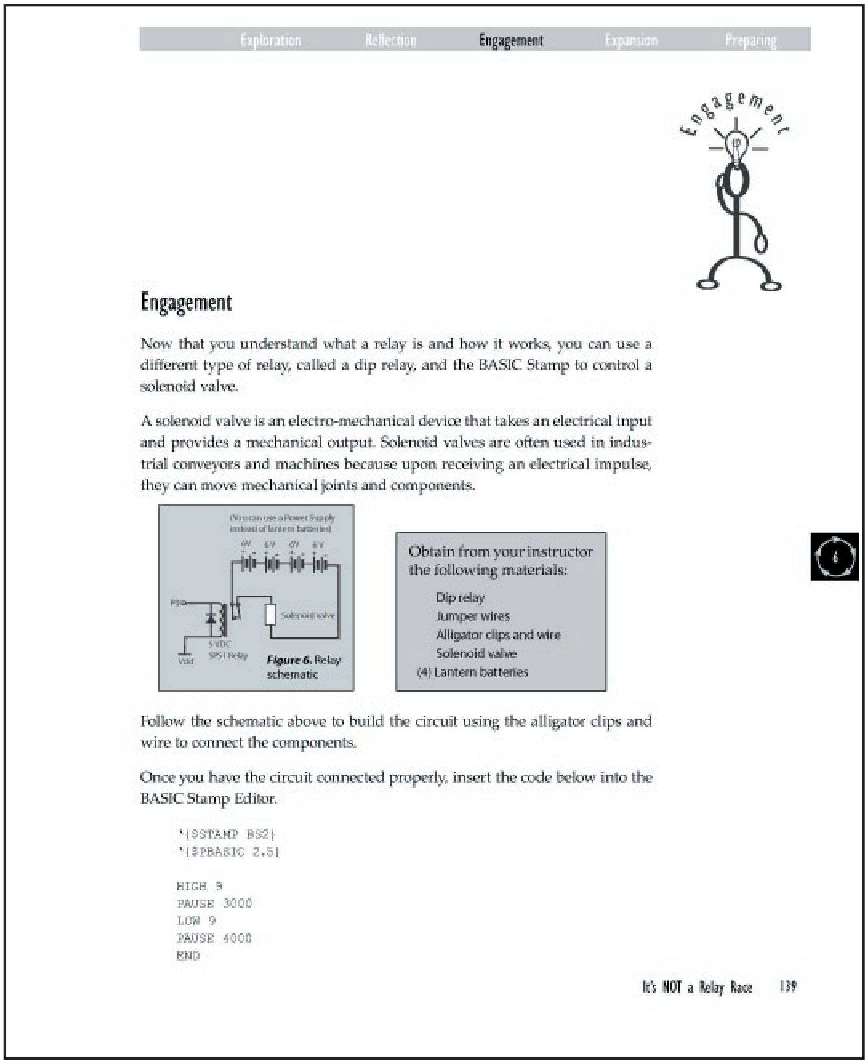
3. What types of devices are controlled by relays?
   Relays are used when a very small amount of current is needed to operate a switch that can handle a larger amount of current.



Exploration Reflection Engagement Expansion Preparing

Engagement

Now that you understand what a relay is and how it works, you can use a different type of relay, called a dip relay, and the BASIC Stamp to control a solenoid valve.

A solenoid valve is an electro-mechanical device that takes an electrical input and provides a mechanical output. Solenoid valves are often used in industrial conveyors and machines because upon receiving an electrical impulse, they can move mechanical joints and components.

Figure 6. Relay schematic

Obtain from your instructor the following materials:

- Dip relay
- Jumper wires
- Alligator clips and wire
- Solenoid valve
- (4) Lantern batteries

Follow the schematic above to build the circuit using the alligator clips and wire to connect the components.

Once you have the circuit connected properly, insert the code below into the BASIC Stamp Editor.

```
'{$STAMP BS2}
'{$PBASIC 2.5}

HIGH 9
PAUSE 3000
LOW 9
PAUSE 4000
END
```

It's NOT a Relay Race 139

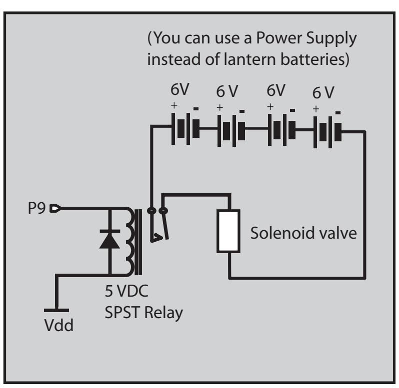


Figure 6. Relay schematic

Engagement

The *Engagement* phase allows the students to use a dip relay with the BS2 to control a solenoid valve. This activity will help the students complete the *Primary Challenge.*

A solenoid valve is an electro-mechanical device that takes an electrical input and gives a mechanical output. Solenoid valves are often used in industrial conveyors and machines because upon receiving an electrical impulse they can move mechanical joints and components.

Students are asked to enter the following program into the BASIC Stamp Editor software:

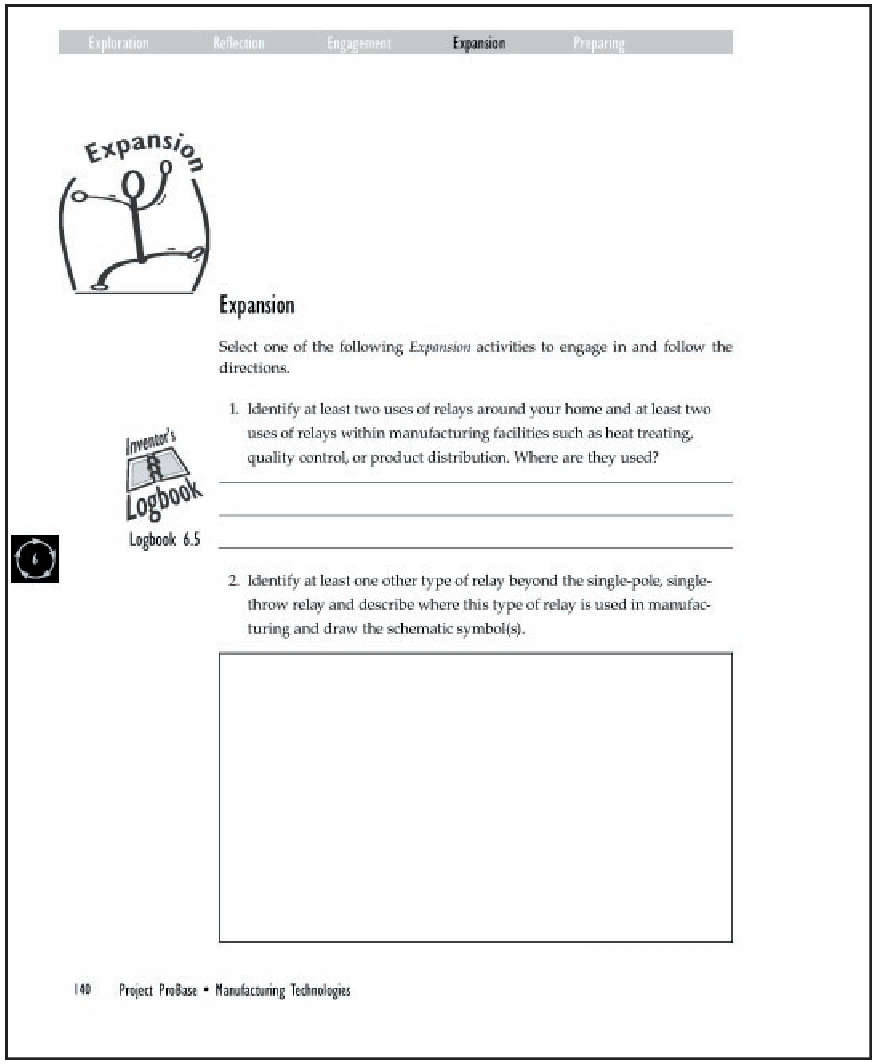
```
'{$STAMP BS2}
' {$PBASIC 2.5}

HIGH 9        Turns pin 9 on
PAUSE 3000    Keeps pin on for 3 sec.
LOW 9         Turns pin 9 off
PAUSE 4000    Keeps pin off for 4 sec.
END           Ends the program
```

The above program allows the valve to be activated for three seconds before the program ends. If students would like the program to continuously loop, the "DO" command can be inserted above the "HIGH 9" command and the "LOOP" command can replace the "END" command.

Expansion

Although not required, these *Expansion* activities are designed to cause teams to delve deeper into the concepts explored in this learning cycle.

Students should select only one of the following *Expansion* options.



Expansion

Select one of the following *Expansion* activities to engage in and follow the directions.

1. Identify at least two uses of relays around your home and at least two uses of relays within manufacturing facilities such as heat treating, quality control, or product distribution. Where are they used?
2. Identify at least one other type of relay beyond the single-pole, single-throw relay and describe where this type of relay is used in manufacturing and draw the schematic symbol(s).

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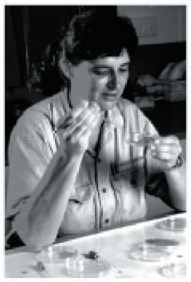
1. Identify at least two uses of relays around your home and at least two uses of relays within manufacturing facilities such as heat treating, quality control, or product distribution. Where are they used?
2. Identify at least one other type of relay beyond the single-pole, single-throw relay and describe where this type of relay is used in manufacturing and draw the schematic symbol(s).
3. Disassemble a discarded product such as a VCR, stereo system, or electric appliance to find out how relays are incorporated into the design and how they affect the functionality of the device. Record your findings in the space provided.

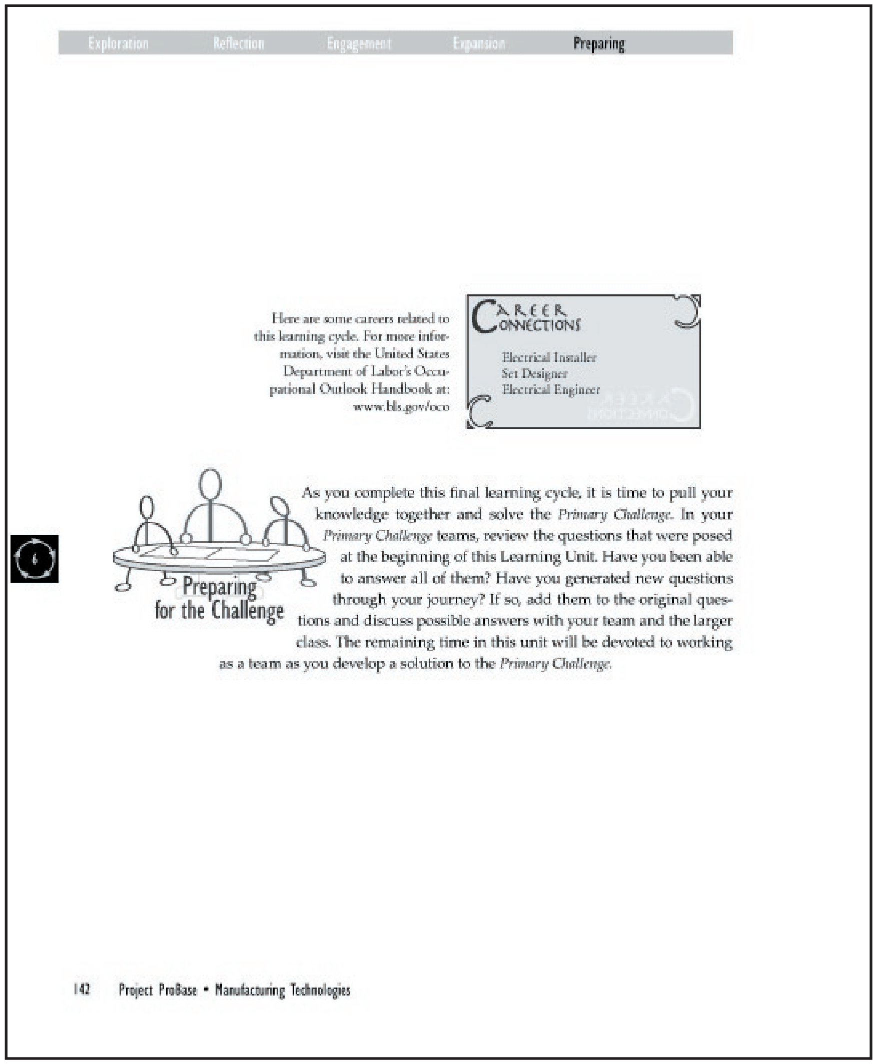


3. Disassemble a discarded product such as a VCR, stereo system, or electric appliance to find out how relays are incorporated into the design and how they affect the functionality of the device. Record your findings in the space provided.

Notes:

Preparing for the Challenge

As students complete this final learning cycle it is time to begin working full-time on the solution to the *Primary Challenge.* Allow students some time in their *Primary Challenge* teams to review the questions posed at the beginning of this Learning Unit. As a team, they should determine whether or not they have been able to answer all of these questions. They should also be able to add some questions to this list- questions that have been generated through their experiences in the learning cycles. Encourage students to reflect on their conceptual growth through this Learning Unit.



Exploration Reflection Engagement Expansion **Preparing**

Here are some careers related to this learning cycle. For more information, visit the United States Department of Labor's Occupational Outlook Handbook at: www.bls.gov/oco

CAREER CONNECTIONS

Electrical Installer
Set Designer
Electrical Engineer

Preparing for the Challenge

As you complete this final learning cycle, it is time to pull your knowledge together and solve the *Primary Challenge*. In your *Primary Challenge* teams, review the questions that were posed at the beginning of this Learning Unit. Have you been able to answer all of them? Have you generated new questions through your journey? If so, add them to the original questions and discuss possible answers with your team and the larger class. The remaining time in this unit will be devoted to working as a team as you develop a solution to the *Primary Challenge*.

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Student Assessment

An assessment rubric has been developed for the *Exploration* and *Engagement* activities. Feel free to change this rubric to better suit your particular needs.

It's NOT a Relay Race

Element	Criteria				Points
	4	3	2	1	
Exploration	Completed every activity with exceptional quality.	Completed activities with above average quality.	Completed most of the activities with average quality.	Completed some of the activities and/ or with below average quality.	
Engagement	Completed activity with exceptional quality.	Completed activity with above average quality.	Completed activity with average quality.	Completed activity with poor quality.	
Inventor's Logbook Entries	Fully answered all entries and provided good examples.	Answered most of the entries and provided some examples.	Answered few entries and provided few examples.	Did not answer entries and did not provide examples.	
Expansion	Completed one of the activities with exceptional quality.	Completed one of the activities with above average quality.	Completed one of the activities with average quality.	Did not complete one of the activities or was poor quality.	
				Total	

6

Appendix and Supplemental Materials

Appendix

Manufacturing Technologies

Inventor's Logbook

Name: Date: Activity:

W h to

Teamwork Rubric

Observation of:	Criteria				Total Points
	4	3	2	1	
Helping - students offer assistance to one another	Consistently	Most of the time	Some of the time	None	
Listening - students work each others' ideas	Consistently	Most of the time	Some of the time	None	
Participating - students contribute to project/activity	Consistently	Most of the time	Some of the time	None	
Persuading - students exchange, defend, and rethink ideas	Consistently	Most of the time	Some of the time	None	
Questioning - students interact, discuss and pose questions to all team members	Consistently	Most of the time	Some of the time	None	
Respecting - students encourage and support ideas and efforts of others	Consistently	Most of the time	Some of the time	None	
Sharing - students offer ideas and report their findings to each other	Consistently	Most of the time	Some of the time	None	
Collaborative - overall team work	Consistently	Most of the time	Some of the time	None	
				Total Points	

Additional comments:

General Discussion Rubric — Manufacturing Technologies

Element	Criteria				Total Points
	4	3	2	1	
Interpretation - Understanding of issues, concepts, questions, ideas, topics	- Explores implications of issue and goes beyond it - Accurately states and identifies issues - Expresses relevant knowledge base based on own thoughts	- Explains aspects of issues - Accurately states issues - Expresses relevant knowledge base based on own thoughts	- Understands issues - States relevant factual, ethical, or definitional issue as a question -Expresses relevant knowledge base based on another's idea	- Does not state issues - Does not express relevant base knowledge	
Evidence - Support of comments	- Uses strong evidence relevant to specific issue - Draws connections with other relevant items and prior knowledge - Explains how it supports thoroughly	- Uses strong evidence relevant to specific issue - Explains how it supports	- Uses weak evidence relevant to specific issue - Briefly explains how it supports	- Does not provide evidence relevant to specific issue	
Listening and Responding - Commenting on others' ideas	- Invites comments from others - Compares own ideas to others' - Agrees/disagrees with specific parts and explains reasons - Reassesses own stance	- Invites comments from others - Explains reasons for agreeing or disagreeing - Adds to or challenges others' ideas	- Summarizes others' ideas - Agrees or disagrees with other ideas	- Only listens to others speak, does not respond - Copies other ideas - Disruptive	
Participation - Contribution to discussion	- Participates willingly - Takes a leadership role - Asks specific questions	- Participates willingly - Asks questions	- Participates only when called on	- Does not participate in class discussion	
				Total Points	

Sample Product Questionnaire (Results and Example Analysis Included)

Candy Land, Inc.

Please help us serve our customers better by taking a few minutes to complete this survey. Simply circle the answer that best describes you.

Total number who completed the survey: 10

1. Gender

A. Male:_5_ B. Female:_5_

Example of Statistical Analysis:

2. Do you eat candy at least once a week?

A. Yes:_7_ 70% of total

4 males = 57% answering yes were males and 80% of all males answered yes

3 females = 43% answering yes were females and 60% of all females answered yes

B. No:_3_ 30% of total

1 male = 33% answering no were males and 20% of all males answered no

2 females = 67% answering no were females and 40% of all females answered no

3. Where do you purchase (or get) candy most often?

A. Grocery Store:_1_*(1 male)*

B. Home:_5_*(3 males, 2 females)*

C. School:_3_*(1 male, 2 females)*

D. Other:_1_*(1 female)*

4. What is your favorite type of candy? Hard candy or soft, chewy candy?

A. Hard candy:_6_*(4 males, 2 females)*

B. Soft, chewy candy:_4_*(1 male, 3 females)*

5. Of the following, what is your favorite flavor of candy?

A. Chocolate:_5_*(2 males, 3 females)*

B. Fruit flavors:_2_*(2 males)*

C. Caramel or Butterscotch:_2_ *(2 females)*

D. Mint:_1_*(1 male)*

6. What influences your decision on which type of candy you buy most often?

A. Cost:_3_ *(2 males, 1 females)*

B. Mood/Appetite:_1_*(1 female)*

C. Flavor:_2_ *(2 females)*

D. Varies:_4_*(3 males, 1 female)*

Material & Process Evaluation

For the Process Family, indicate how the part was processed when the product was manufactured.

Sub-Component	Material Family				Process Family			
	Metallic	Wood	Ceramic	Plastic	Forming	Fabricating	Separating	Conditioning

Design Principles Student Worksheet

Design Questions	Provide a rating from 1-5 for each sample product within each category				
	Sample 1	*Sample 2*	*Sample 3*	*Sample 4*	*Sample 5*
1.______________________________?					
2.______________________________?					
3.______________________________?					
4.______________________________?					
5.______________________________?					
Total Score					

Team Name: ____________________

Team Leader: ____________________

List of responsibilities: ____________________

Design: ____________________

1. ____________________
2. ____________________
3. ____________________
4. ____________________

Marketing: ____________________

1. ____________________
2. ____________________
3. ____________________
4. ____________________

Finance: ____________________

1. ____________________
2. ____________________
3. ____________________
4. ____________________

Ergonomics/Safety/Environment: ____________________

1. ____________________
2. ____________________
3. ____________________
4. ____________________

Project ProBase
Enduring Understandings & Essential Questions

Students will understand:

1. that **technological progression** is driven by a number of factors, including individual creativity, product and systems innovation, and human wants and needs.
    a. How are new technologies **developed and marketed**?
    b. What social, cultural, and political **pressures** lead to the need or want for new technologies?
    c. What are the specific **roles of professionals** involved in technological adaptation and change?
    d. What **factors** need to be in place for new technologies to be viable in the national and international marketplace?
    e. What are the fundamental **processes/principles** used to develop new technologies?

2. that **technological** development for the solution of a problem in one context can **spinoff** for use in a variety of often unrelated applications.
    a. How do **technologies migrate** from one context (or location) to another and what are the implications?
    b. What **roles** do the patent, trademark, and copyright laws play in the **dissemination of** technological **ideas**?
    c. How have technological innovations caused **paradigm shifts** throughout history and what are these major shifts?

3. that **technological change** can be positive and/or negative, and can have intended and/or unforeseen social, cultural, environmental, and political consequences.
    a. What are some of the unforeseen **consequences** of specific technological changes throughout history?
    b. How can a technology cause both good and harm and how do humans prepare for or respond to these **impacts**?

4. how **technological systems** work, the components of those systems, and how they fit into the larger technological, economic, and social systems.
    a. What are the systems and **subsystems** involved in the various contexts of technology?
    b. What are the key elements of the various technological **systems** and what are the **relationships** between these systems?
    c. How do various technological **systems influence** the economy, society, the environment, and culture?

5. that there are compelling and controversial **issues** associated with the acquisition, development, use, and disposal of **resources**.
    a. What kinds of **resources** are required in each of the eight technological contexts?
    b. What is the **relative value** of specific resources used in technological systems?
    c. To what extent have **resource** issues (acquisition, development, use, and disposal) **affected** the direction of technological **development**?
    d. What **resources** are **needed** to solve a specific design problem (people, information, materials, tools, capital, energy, time, technical ability)?

Students will understand:

6. that the complexities of technological **design** involve **trade-offs** among competing **constraints** and requirements, including engineering, economic, political, social, and environmental considerations.
    a. To what extent have **optimal designs** been achieved in the eight technological context areas?
    b. What are the key **factors** that cause designers to make decisions about trade-offs, limitations, and constraints when designing new products and systems? (**Micro Factors**)
    c. How can members of the public, politicians, or the state of the economy **influence** the design of new technological products and systems? (**Macro Factors**)
    d. How can **social values** and **principles** guide in the development of solutions to technological problems?

7. that **technological design** is a systematic **process** used to initiate and refine ideas, solve problems, and maintain products and systems.
    a. What are the five primary **methods** through which technological **problems** are **solved** and how do they differ (i.e., troubleshooting, research and development, experimentation, invention and innovation, design problem solving)?
    b. To what extent can design problems be approached through a series of generic procedures (the **design loop**)?
    c. What **design criteria** is typically considered when developing new technologies (i.e., marketability, safety, useability, reliability, cost, materials, etc.) and how do these influence the final product/system design?
    d. How are **decisions** made regarding **information** that should be discarded or ignored?
    e. How can the **attributes** of design and the **principles** of design aid in the development of quality solutions?
    f. How can the establishment of relationships, controlling variables, categorizing techniques, and making inferences aid in the **development** of **new** technological **designs**?

8. how to **evaluate** the benefits, limitations, and **risks** associated with existing and proposed technologies.
    a. How does a **risk/benefit analysis** aid the designer in addressing potentially harmful effects prior to development?
    b. What are some important **ethical decisions** that should be considered when developing any new technology?
    c. Are all product/system **designs** created for the purpose of adding **social value**?
    d. How are ethical **considerations**, economic considerations, engineering realities, and political forces **balanced** during technological innovation?
    e. In what ways are technological needs and wants being **balanced** with long term environmental or social **consequences**?

9. how to **utilize** a variety of simple and complex **technologies**.
    a. How are technologies used to **control devices** and systems?
    b. How do technologies **communicate** with one another and provide information to humans?
    c. To what extent are technological systems and **devices controlled** by people and to what extent are they controlled by other technologies?
    d. How is technological **instrumentation** used to measure, calculate, manipulate, and predict the actions of technological devices and systems?

SCALE:

ASSIGN:

DATE:

TITLE:

DRAWN BY:

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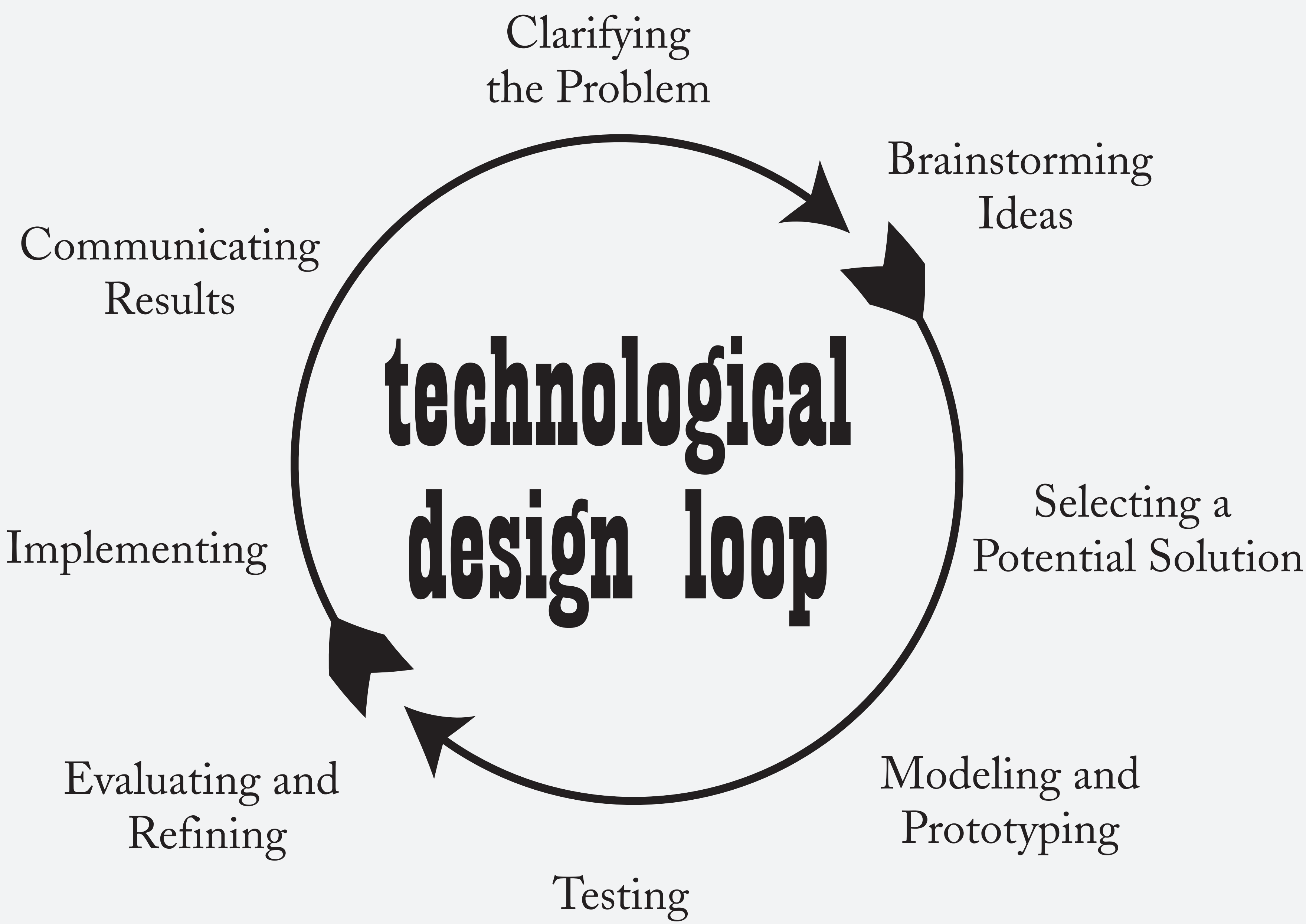
technological design loop
Clarifying the Problem
Brainstorming Ideas
Selecting a Potential Solution
Modeling and Prototyping
Testing
Evaluating and Refining
Implementing
Communicating Results

In addition to ***Manufacturing Technologies***, the ProBase curriculum series offers seven other Learning Units. The eight ProBase units can be used independently, in conjunction, or as an entire curriculum package. A brief description of each of the ProBase learning units follows. For more information, contact the Center for Advancing the Teaching of Technology and Science.

Energy and Power Technologies

This unit examines how energy and power systems can be made more efficient and how they may be utilized in problem solving. The unit also focuses on how modern energy and power systems impact cultures, societies, and the environment.

Medical Technologies

This unit provides an analysis of how medical technologies are used to increase the quality and length of human life, and how increased use of technology carries potential consequences, which require public debate. The tools and devices used to repair and replace organs, prevent disease, and rehabilitate the human body are also explored.

Agriculture and Related Biotechnologies

This unit provides an analysis of the various uses and ethical considerations of biotechnology. The unit also examines how agricultural technologies provide increased crop yields and allow adaptation to changing and harsh environments, enabling the growth of plants and animals for various uses.

Information and Communication Technologies

This unit examines how technology facilitates the gathering, manipulation, storage, and transmission of data and how this data can be used to create useful products. The unit also explores how communications systems can solve technological problems.

Construction Technologies

This unit explores the factors influencing the design and construction of various structures, including the infrastructural elements, community development factors, and environmental considerations. In addition, the unit provides experience with hands-on construction techniques and with modeling structures to scale.

Entertainment and Recreation Technologies

The unit explores technological entertainment and recreation systems and how their use impacts human leisure-time performance. The social, cultural, and environmental implications of entertainment and recreation technologies are also examined.

Transportation Technologies

This unit looks at the complex networks of interconnected subsystems that comprise transportation systems and the roles of these components in the overall functional process of transportation. The unit also provides an analysis of the improvements and the impacts of transportation technologies on the environment, society, and culture.